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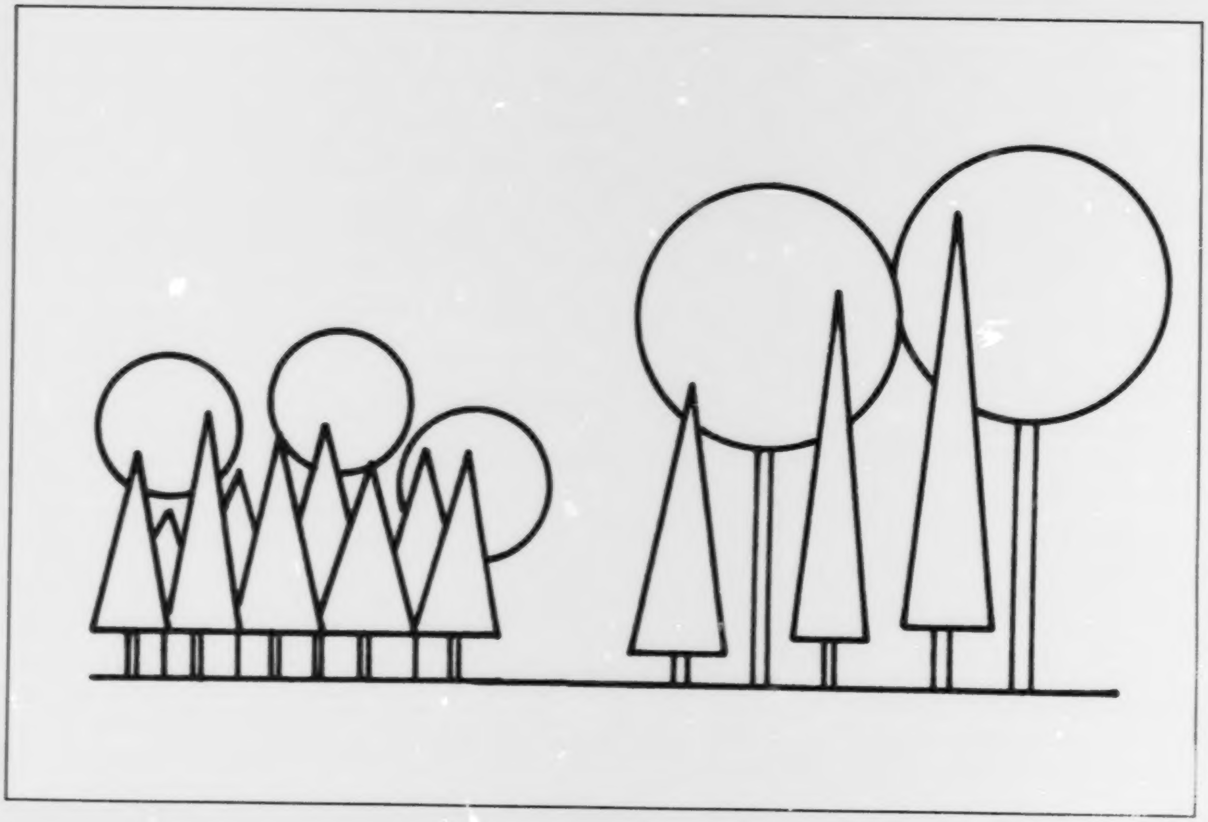

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## FORESTRY CANADA, ONTARIO REGION

Ontario Region is one of six regional establishments located across Canada and operated by Forestry Canada. The overall objective of Forestry Canada is to promote the preservation, enhancement and wise use of a healthy, attractive and bountiful forest resource and terrestrial environment for the economic and social benefit of all Canadians. Ontario Region pursues this objective by conducting two major programs: research and technical services and forestry development. Both programs address major problems affecting forest management and the forest environment primarily in Ontario, but because of the transprovincial nature of the forest resource, many elements of our research program are of national significance.

Ontario Region specializes in research in forest production, forest protection, forest environment and forest utilization. These programs deal directly with the issue of maintaining and enhancing the resource supply. Activities range from basic to applied and developmental research, and include a significant technology transfer component.

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Close working relationships are maintained with the Ontario Ministry of Natural Resources, the forest industry, educational institutions specializing in forestry and the biological sciences, and other forestry organizations within the province. Ontario Region is represented on the Ontario Forestry Council and the Ontario Forestry Research Committee, which have responsibility for coordinating forestry research in Ontario.

It is recognized that forested land must be managed in the best public interest, not only for the wood production essential to our economy, but also for the recreational purposes that are so important to our social well-being. This must be achieved in a manner that will maintain or improve the quality of the forest environment and preserve it for generations to come.

# Space to Grow:
## spacing and thinning in northern Ontario.

Proceedings of a symposium sponsored by Forestry Canada, Ontario Region,
and the Ontario Ministry of Natural Resources.

18-20 June 1990
Water Tower Inn, Sault Ste. Marie, Ontario

V.F. Haavisto, C.R. Smith and C. Mason, *Editors.*

Forestry Canada
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1991

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Joint Report 15

91-05428/

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Catalogue No. Fo 29-11/15E
ISBN 0-662-18768-7
ISSN 0832-7157

Copies of this publication are available at no charge from:

Communications Services
Great Lakes Forestry Centre
Forestry Canada-Ontario Region
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Microfiches of this publication may be purchased from:
Micro Media Inc.
Place du Portage
165, Hôtel-de-Ville
Hull, Québec
J8X 3X2

# ACKNOWLEDGMENTS

According to the follow-up evaluation of "Space to Grow", 95% of forest technicians and 84% of foresters in attendance at the conference answered "yes" to the question "Were your expectations met?" This high approval rating is attributable to the team of individuals who contributed their ideas and energies towards this event.

I would like to first extend special thanks to the Program Committee Co-chairpersons Chuck Mason (Forest Resources Group [FRG], Ontario Ministry of Natural Resources [OMNR]) and Fred Haavisto (Forestry Canada, Ontario Region [FCOR]), who were instrumental in formulating a highly informative and provocative program around the theme of spacing and thinning, and in assembling the impressive list of speakers, rapporteurs and moderators from Ontario, across Canada, from the U.S. and from overseas. Providing valuable assistance and a broader perspective in the development of the program were committee members Barney Smith (OMNR/FRG), Rob Galloway (Northern Forest Technology Development Unit, OMNR), Brian Nicks (E.B. Eddy Forest Products Ltd.), and Jean-Denis Leblanc and Fred von Althen (FCOR). I also thank Barney for handling exhibits and Jean-Denis for assisting with French translations.

For providing first-class facilities, and for creating a memorable ambiance that successfully fostered effective communication between all participants, I would like to thank the hard-working members of the Facilities and Organizing Committee. Many thanks for the professional efforts of Co-chairpersons Guy Smith (FCOR) and Celia Graham (OMNR/FRG) and committee members Dave Kennington (FCOR) and Cindy Krishka (OMNR, Tweed). Thanks are also due to Eleanor Biluk (FCOR) and Annie Grimard (OMNR/FRG) for assisting this committee. Additional thanks go to Eleanor for completing the meeting evaluation.

In the production of this proceedings, the diligent efforts of Fred Haavisto are gratefully acknowledged in the technical editing and associated compilation of the majority of papers. Joanne Bremner (FCOR) provided invaluable input in the overall compilation of the text, transcription of papers, word processing, and editing assistance. Special thanks to Geoff Hart (FCOR) for his timely and efficient final editing and overall guidance and administration of the various aspects of publication, and to Joanne Theriault (FCOR) for formatting text for final publication. Many thanks to Peter Jakibchuk and Dave Kennington (FCOR) for the preparation of illustrative materials. Peter also oversaw design and layout of the publication.

The primary sponsors of Space to Grow were Forestry Canada, Ontario Region, and the Ontario Ministry of Natural Resources. We gratefully acknowledge additional sponsorship from Algoma Central Properties Ltd., Southex Exhibitions, and St. Marys Paper Inc.

C.R. Smith
Chairperson
Space to Grow

# Space to Grow

## by Bill Botti

Way, way back in the early ages,
life on earth had different stages.
For a million years 'twas filled with roars
of monstrous beasts called dinosaurs.

Many strange beasts walked the land,
unusual things on every hand.
There were some insects, such as ants,
and ferns and algae were the only plants.

One day as God was passing through,
an idea dawned, for something new.
He conjured up the mice and camels
and thus began the age of mammals.

Some fresh ideas, he tried on these,
like hair and lips and mammaries.
And all were good in his opinion
and then he gave to Man, dominion.

"Go multiply; subdue the earth."
And this they did with glee and mirth.
'Til one day, they could find no haven
for all the world had been clean shaven.

"Oh, Lord," they said, "What shall we do?
We see the need for something new,
We need food and we need shelter,
We need shade so we won't swelter."

"OK", said God, "I clearly see
that now's the time to invent the tree.
But what's to build with? Nothing's there.
All that's left is water 'n' air."

So, God made leaves and God made wood
and then he saw that it was good.
He formed them into a living tree
that grew and breathed, what a sight to see!

Then many woods with various uses
and leaves and fruits with tasty juices.
And seeds He made with wings to fly.
Some for wetlands; some for dry.

He spread them over all the land,
some as loners, but most in stands.
But the part that's surprisin' – I stop and stare –
This magical tree's made of water and air.

Once trees were invented, God planted and grew 'em
and then He told Man, "You're quite welcome to 'em.
These are for you to harvest and use 'em,
take what you need, but please don't abuse 'em."

So, God, in His wisdom, perceived there was needed,
some way to ensure that his warning was heeded.
He selected some daughters and some of his sons,
some of his very most promising ones.

He gave them the knowledge they needed to know
concerning the trees and how they grow.
He taught them site index and tolerance of shade,
genetics and silvics and soon He had made

A new field called Forestry of which we're a part.
Some call it a science; some say it's an art.
But we at this conference all know you can't say
in one or two words what we do every day.

We know that it's science and art and it's true,
there's a fair bit of gambling and luck in it, too.
We don't know it all, but enough to get by.
There's always new questions and new things to try.

But what it boils down to, this Forestry stuff,
it's a jungle out there and conditions are tough.
God's willing to help us and this much we know,
*He'll* do the work, *we* provide space to grow.

*Bill Botti is Program Leader – Timber Management, Forest Management Division, Michigan Department of Natural Resources, Lansing, Michigan.*
*Bill composed this poem for Space to Grow.*

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# *Opening Remarks and Keynote Address*

# OPENING REMARKS

*G. Oldford*
*Director, Forest Management Branch*
*Ontario Ministry of Natural Resources*
*Sault Ste. Marie, Ontario*

I am delighted to welcome you to this conference. This conference comes at a time when our Ministry is actively exploring new ways to address the silvicultural needs of the future as they relate to the forest industry and to the other growing demands on our forests. These proceedings are part of that exploration.

As concern for our forests builds in the public domain and as the security of future wood supplies has become an international issue, we look forward to learning about the successes of other jurisdictions in improving wood supply. At the same time, we will hear about our own successes in protecting forests as a part of our global resource.

You are going to hear about other silvicultural techniques that have an important role to play in securing our future wood supply. I invite you to discuss those techniques and take every opportunity to learn and apply them to the Ontario situation and to help us address the challenges of the new age in forestry.

It certainly is not news to people in this room that those of us in forest management are undergoing a lot of soul searching these days. In Ontario, we are being encouraged to re-examine our policies from the bottom up. Indeed, this examination — a second look at our entire focus — is a reflection of the public's growing commitment to environmental issues and the non-commercial values of the forest estate. As the world shrinks, as population levels rise, and as we see the impacts of our actions on the ecosystem, our thinking must change.

Our practices today in forestry are coming under increasing scrutiny, and we must be seen to embrace the environmental concerns of the public. The purpose of forestry is pretty simple, and Jeffrey Pinchot made that pretty clear when he said, "It is to produce goods and services that society demands from its forests." I would only add "at a given point in time", for it is quite evident that some of those demands are changing.

Not so long ago we saw the forests mainly as a production area for volumes of timber and as a revenue producer. Now we see them as carbon sinks, oxygen producers and a home for wildlife. We look to the forest to prevent erosion, to guarantee plant and animal diversity, and to enhance cultural aspects of our society. Increasingly, people look to our forests as centers of refuge, relaxation and spiritual renewal.

The list of goods and services Society demands from its forests is growing, and will continue to grow. Those demands are sometimes complex and sometimes inconsistent, reflecting the conflicts that society is experiencing. But let me say that I believe very strongly in the resilience of the forest in meeting these demands on a sustained basis, with the careful management that is part of a future-oriented framework.

We in Ontario are committed to developing such a policy framework to ensure the sustainable development of our forest. In essence, we are determined to use the forest today in a way that will not jeopardize the ability of future generations to use it as well. This conference is set in the context of our need for a new forest framework in Ontario. Any way we cut the pie, the job is to produce more volume on a decreasing land base.

Twenty years ago the existing Forest Production Policy was created to guide our forest management decisions. That initiative resulted in a major commitment to forest renewal. Currently, we are planting more than 163 million trees annually. However, we are largely renewal-based; our tending activities are largely related to maintaining and protecting established plantations. It is time to improve our management in that area of the forest that is past the renewal stage, in stands that are 15 and 20 years old, or older. The focus of this conference is very much in tune with our needs today.

There are many questions to be answered. How can these techniques help secure future wood products? What products can we produce and at what cost? Can they enable us to increase our wildlife population? How do they fit into a framework that we have to put in place in this province to provide for a secure and healthy forest estate? We have an opportunity to address these questions here over the next two days. I wish you luck.

# OPENING REMARKS

*Dr. C. Winget*
*Regional Director General*
*Forestry Canada, Ontario Region*
*Sault Ste. Marie, Ontario*

It truly is a privilege for me to offer Forestry Canada's welcome to you this morning. I'm very pleased with the attendance that we have, all of the staunch Ontario people, of course, but many from other provinces, from south of the border and some from overseas. Our keynote speaker from British Columbia, Mr. Les Reed, was my boss in a former incarnation, so I know we will start the conference with some very eloquently expressed opinions.

I am somewhat startled and very pleased with the dimensions this event has attained. In the beginning, it was really thought of as a rather small workshop but obviously this is a theme whose time has come. As Gord Oldford mentioned, we in Ontario have focused for many years, even decades, on forest renewal. Now we must shift our attention to tending, the next phase of responsible silviculture and intensive forest management.

The opporunities are most certainly there. We need only consider the huge areas of juvenile jack pine in this province, available at scales ranging from a few tens to a few tens of thousands or even hundreds of thousands of hectares. We have not been very successful in managing the mixedwoods of the boreal forest, often our most complex stands and occupying our most productive sites in that zone. Given a good deal of courage, one can also consider the problems of the tolerant hardwoods on the Canadian Shield, with the eternal difficulties of very large amounts of low-quality material for which there are limited markets to pay even removal costs. In all, the last thing we lack is opportunity. What we do lack is the structured expertise and planning framework to make the transition to this next phase of our silvicultural evolution. Obviously, the first needs are to evaluate existing information, consolidate it into a relevant knowledge base, and begin asking the questions about what shifts we want to make and how we can make them. This conference is an initial step in that process.

I trust that the foresters of Ontario will not be parochial, insisting on "made in Ontario" solutions. Logically, we must beg, borrow, steal and sometimes even buy good ideas from anybody, anywhere, anytime. Again, this conference is a first step and the reason for inviting many of you to attend. We have much to do in the areas of biology and of silvicultural methodologies relating to stand reactions to treatments and also to linkages of treatments with the desired endproducts, be they fiber or other. We also have the major problem of finding methods that can be applied with reasonable cost-effectiveness to large areas, indeed to immense areas compared with those in some parts of eastern Canada or Europe. Across the north, the known but labor-intensive traditional approaches often do not apply. To some degree, this conference touches on management objectives, strategies and systems. We will have to intensify these efforts in the future, for example, in integrating forest ecosystem classification and geographical information systems (GIS) technology into decision-support systems for tending. This will take time.

Our most critical need is to study options, evaluate priorities and plan where to concentrate first for maximum effect. To blindly rush in with the intent of tending every hectare that needs it in northern Ontario would simply disperse resources to the point of having no measurable impact. We must determine where the high payoffs really are.

I won't dwell on the environmental aspects, which Gord Oldford has already covered very effectively, other than to agree that, clearly, we must approach tending within the context of environmental guidelines, sustainable development and multiple benefits. Otherwise, we can simply forget the exercise — it won't work.

There are background elements, largely uncontrollable or unpredictable, that we should keep in mind. Concern about acid rain and ozone damage is diminishing, but both are still potential hazards. Conversely, concern for climate warming is increasing, with significant effects anticipated on a time scale approximately that of one plantation rotation, suggesting increased investment risks, especially from fire. To some degree, changing patterns in trade, in fiber needs and in product demand, in wild cards such as recycling, and non-tariff barriers (e.g., the pinewood nematode) may have impacts on tending strategies. Not that these factors should deter us in any way, simply that we should take them into account as best we can and on a contingency basis.

In acquiring and consolidating the needed knowledge base for tending, we are obviously going to encounter a wide range of levels of applicability. Some will require a fairly simple transfer process involving only some training and operational experience, leading directly to application. Often, an appreciable degree of development or adaptation will be needed for application in our context. Sometimes, real knowledge gaps will be identified and research will have to be initiated, recognizing the time and costs involved. In fact, I suspect that there is a very heavy workload in each of these areas. One of the goals of this meeting and the follow-up to it is to define those needs so that the research and technology development and transfer agencies can collectively develop action plans in a context of partnership. This could be a logical role for the Ontario Forest Research Committee, which has provincial, federal and industrial representation.

In closing, let me reiterate that I am very encouraged by the level of participation in this meeting, as well as by the recognized expertise of the contributors. I am certain that this conference will provide the quick start we need.

# OPENING REMARKS

*J. Fratesi*
*Mayor*
*Sault Ste. Marie, Ontario*

Ladies and gentlemen, it is certainly my pleasure to be here this morning as the mayor of Sault Ste. Marie to bring you an official welcome to the city; more importantly, I am here to bring you the warm greetings of the people of Sault Ste. Marie as you embark upon your conference.

Sault Ste. Marie has been known for a lot of things in its history, but one of the things that we pride ourselves on is our involvement, over many years, in the forestry aspect of our country. Sault Ste. Marie has the honor of being the "Forestry Capital of Canada" for 1990, and with this being "Forestry Week" in our city, the conference ties right into the significance that forestry plays in our community. It is for this reason that it is a double pleasure for me to be here.

In our community, there is a significant presence, both federally and provincially, with respect to management of and research concerning our forests. More specifically, we have Forestry Canada's Ontario Region (the Great Lakes Forestry Centre) and Forest Pest Management Institute for the federal side. Provincially, we have a district office of the Ontario Ministry of Natural Resources and the Forest Resources Group's head office staff (who are in temporary quarters but who will soon be occupying one of the largest and most modern buildings on the waterfront). We have the province's Ontario Forest Fire Control Centre. Under construction, and to be occupied this fall, is the province's forest research facility, the Ontario Forest Research Institute. Sault Ste. Marie is also home to one of the four forest technical education centres in the province, the Sault College of Applied Arts and Technology. Our city has, for many years, been involved in the lumber and paper industries. It is indeed gratifying for me to be here today, to look at your agenda and to see people such as the previous two speakers, who are residents of Sault Ste. Marie. It is with a sense of pride that I say this and also acknowledge that it appears that things are in good hands with folks like you together for a conference such as this.

So I would like to take this opportunity to thank the federal and provincial governments for sponsoring this worthwhile effort. It will be not only for the benefit of Ontario; hopefully your participation in this will be significant in that you will take the results back to your jurisdiction, share with us those points that are important to you, and allow us to share with you those points that we believe are important.

With that I would like to wish you all well in this conference and hope that your stay in Sault Ste. Marie is a pleasant one. We hope that you have reason to come back some other day to visit with us and enjoy what Sault Ste. Marie has to offer.

# KEYNOTE ADDRESS: THE CENTRAL ISSUE IN CANADIAN FORESTRY

*F.L.C. Reed*
*NSERC/Industry Chair in Forest Policy*
*Faculty of Forestry, University of British Columbia*
*Vancouver, B.C.*

## INTRODUCTION

It is a genuine pleasure to participate in this most important conference. The theme, Space to Grow, could not be more timely. The province of Ontario is facing serious timber deficits, as is the case in the other provinces and, indeed, in every region of this continent.

My objective is to throw out a challenge to forest land managers and policymakers alike. In doing so I intend to set the stage by speaking first of the reality of timber deficits (and of myths to be debunked), then of investment criteria, and finally of the central issue in Canadian forestry today. I will not be discussing the *how* of intensive silviculture, but rather the *why*.

## FACING REALITY

There is a stern reality that faces the forestry communities in northern Ontario. I speak of the pervasive sawtimber deficits that seem to be so hard for the Ontario Ministry of Natural Resources to admit to publicly. Lest you think I am picking on this province, let me hasten to say that similar deficits exist in every province. The difference is that in Quebec, British Columbia and other provinces, these shortages are discussed openly.

Make no mistake about it: the reservoir of sawlogs has been drawn down to dangerously low levels near scores of communities. As a result, the forest industry is faced with a profound restructuring in which lumber production will decline, along with the associated output of the residual chips which are so economical and attractive to the pulp and paper sector. How did we get into this predicament? I have discussed this in many papers and will repeat here a part of what was published a year ago in a newsletter of the Forest Economics and Policy Analysis Research Unit at the University of British Columbia (Reed 1989).

It was not long ago that many Canadians thought that we had an inexhaustible forest, that it was much less expensive to deliver wood to mills than was the case for our competitors, and that the world's customers would always beat a path to our door. This kind of complacency has now vanished. Experience has already shown that our lumber producers are not immune to sawlog deficits. Shortages have shut down quite a number of sawmills across Canada since 1980, and others face a similar threat in the years just ahead.

How can we explain this abrupt change in perception from timber abundance to threatened curtailment? There are several reasons. First, losses of mature timber to insects and fire have been much heavier than anticipated. Second, the marketplace has imposed economic-accessibility criteria on our remote forests, forcing a "netting-down" process (in which otherwise suitable stands are excluded from the area that can be harvested because of the high cost of accessing them). To use the language of the B.C. Forest Service, only half of their forested area is presently productive, available and suitable for industrial use. Third, forest renewal has generally not kept pace with the area harvested, either in terms of prompt regeneration or systematic tending of the new plantations, and subsequent improvement of timber stands gets little or no attention. Fourth, the application of logging guidelines has sharply reduced the supply of available timber while increasing the cost of logging the remainder.

Finally, timber availability is reduced because wilderness and recreation enthusiasts have persuaded governments to set aside large timber limits that were scheduled for harvesting in the near future. Just within the last year, the Sierra Club and other local societies have put the forest community on notice that their goal is to at least double the amount of provincial land in single-use categories and old-growth reserves.

What are the facts with respect to the available timber supply? One way to gain perspective is to compare the annual allowable cut (AAC) with recent harvest levels and the approximate industry capacity. In 1986, I combined the provincial softwood AACs and came up with a Canadian total of 166 million $m^3$. This estimate was prepared for the National Forest Congress in Ottawa, and was based on information made available by the provinces. A recent check suggests that no increase in this level is warranted because regeneration success rates are frequently well below target levels, and there are age-class and diameter-class gaps in many localities that raise genuine questions about our ability to sustain the output of quality sawlogs and pulpwood.

In comparison with the AAC of 166 million m$^3$, Canada produced about 175 million m$^3$ of softwood logs from 1987 to 1989, as shown in Table 1 and Figure 1. Meanwhile, our annual softwood processing capacity has probably reached 200 million m$^3$.

Table 1. Comparison of the annual allowable cut and harvest in 1989, by province or region and species group.

| | Allowable cut (million m$^3$) | Harvest (million m$^3$) |
|---|---|---|
| | Softwood species | |
| British Columbia | 77 | 87 |
| Alberta, Saskatchewan and Manitoba | 23 | 14 |
| Ontario | 25 | 24 |
| Quebec | 31 | 33 |
| Atlantic provinces | 14 | 15 |
| | 170 | 173 |
| | Hardwood species | |
| All of Canada | 13 | 60 |

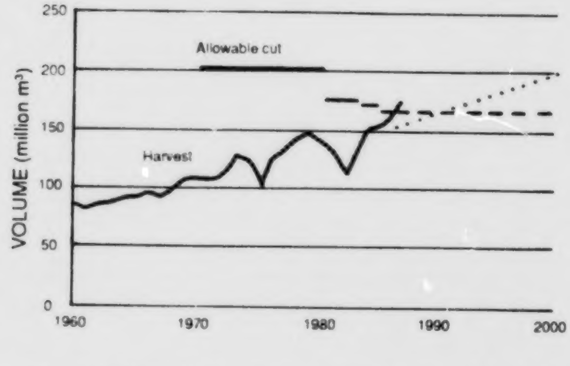


*Figure 1. Canada's harvest of coniferous roundwood in comparison with the estimated annual allowable cut.*

Another complicating factor is the concept of "falldown". This was first discussed widely during the early 1970s, when it was asserted that a reduction (falldown) in the annual allowable cut and harvest was inevitable. In its simplest terms, a falldown means that a second crop grown in 50 to 100 years will not yield the same volume per hectare at harvest as the virgin forest did after 400 years or more. On the contrary, evidence is mounting that intensive forestry can achieve higher volumes in the second harvest.

Unfortunately, the examination of falldown usually considers only reductions in the *volume* of timber that will be available. Virtually nothing is said about the falldown in *quality* that could result from a less attractive species mix, smaller log sizes and a higher incidence of decay. Similarly, little is said about the implications for increased logging *costs* associated with steady declines in volume per hectare in the mature forests being harvested, as well as the necessity for logging in more remote and difficult terrain. The near absence of full public debate about these issues is difficult to fathom.

Is this falldown in timber supply inevitable? Unfortunately, it is, at least given the present level of spending on silviculture and the mix of silvicultural treatments. Nonetheless, this bleak outlook can be changed for the better. Before taking up that challenge, I believe we should clear up some of the widespread confusion that exists. This requires the debunking of some myths and a rethinking of our resource strategy. Some of these myths were described in a recent submission to the British Columbia Forest Resources Commission (Reed 1990), from which much of the following text is taken.

## "ZERO SUM" AND OTHER MYTHS

The most paralyzing of the myths is that the resource pie is fixed and we are therefore caught in a zero-sum game (i.e., a situation in which a gain by any one player implies a corresponding loss by the other players) or an even worse situation. This view is simply nonsense, but it lies at the root of much of our discussion of resource inventories, allowable-harvest levels and tenures. There is a very real sense in which we can choose our own future in forestry. It is true that "they do not make land anymore", but we can certainly do a lot more with the existing land than we have in the past.

Then there is the myth of sustained yield. Yes, we can renew the forest after harvest or natural depletion, and yes, we are doing a reasonably good job today, much better than in 1975. But despite this, we have not managed existing middle-aged stands or new plantations so that falldowns in both volume and quality can be avoided. We are desperately short of sawlogs, with actual or looming deficits in all regions. Some of my critics have said that I don't understand sustained yield, and then they proceed to redefine the term simply to mean prompt regeneration of cutovers. If these same people define sustained yield loosely enough, then of course a falldown is permissible. In my opinion that is unacceptable and borders on being reckless.

There is another deeply held myth invoked by many who believe that the forest industries are tired, inefficient and running on borrowed time. This is contradicted by several measures, and especially by the recovery in employment since the last recession. The forest industry work force in 1989 was 349,000 according to the Labor Force Survey conducted by Statistics Canada. This figure represents an increase of more than 50,000 from the lows reached during the recent cyclical trough, and my hunch is that a substantial share of this improvement is due to increased production of value-added products.

A fourth myth is that overcommitment of the forest and excess capacity in the industry are the fault of provincial governments. Such a charge is only half true. In my view, the industry was equally negligent. They were silent for the most part when forest stewardship was neglected by provincial land managers. Moreover, no one forced industry to invest in excess capacity. It follows that some of the corrective action is the responsibility of the industry.

A fifth myth is that Canada is running short of wilderness. The truth is that we have wilderness in abundance. The conflict we experience daily in some regions is over prime stands of old-growth forest, stands that have been included for decades in allowable-cut calculations on timber licenses. My personal view is that we can and probably should set aside additional forests in wilderness, ecological-reserve and recreational zones. However, this must be done with full regard for the full range of land-use criteria, not the least of which are industry viability and community stability.

The sixth and final myth is that the citizen-taxpayer doesn't care about the cost of reallocating forest land. Unfortunately, the average taxpayer has no awareness that each job in the forest industry is associated with two more jobs in the economy, one in the local community and another in metropolitan or other centers. My own research confirms this. Nor does the taxpayer know that the cost of reallocation of licensed land can be very high in terms of foregone tax revenue, compensation to industry, welfare costs and the disablement of those families which rely directly or indirectly on the forest sector.

## INTENSIVE SILVICULTURE PAYS

The great majority of silvicultural attention in Canada to date has focused on regeneration, and secondarily on rehabilitation of the backlog "not satisfactorily regenerated" (NSR) land that had not been adequately restocked after harvesting or natural depletion. This is reflected in the fact that only 3% of our silviculture budgets are applied to timber-stand improvement. This contrasts sharply with the experience in Scandinavia and much of the United States, where 40 to 50% of silvicultural expenditures are directed towards the improvement of stands older than 20 years.

There are several reasons for the Canadian neglect of existing stands, including the mistaken belief (until recently) that we had an abundance of timber. However, my personal view is that a root cause is the failure of forest economists in academia and in government to go beyond a narrow, textbook approach. They have been preoccupied with the classical expression of forest economics that was written up by Martin Faustmann in 1849; the pedigree of this concept has been examined in a publication (Reed and Baskerville 1991).

The first point to note is the concentration of conservative foresters on volume increments alone, to the virtual disregard of the potential for cost reduction, enhancement of stand values and lessened operational risk. The second point is even more important in communities threatened with an imminent reduction in sawlog availability, and I speak here of the potential for moving stands forward in the harvesting queue (i.e., reducing rotation lengths) by means of thinning, fertilizing and other treatments (Fig. 2).

- Increased harvest volume from the forest as a whole
- Shorter time before stands become operable (i.e., have acceptable sawlog diameters)
- Cost reductions as a result of:
  - shortening hauling distances by treating land near the mill
  - producing larger, more uniform logs for logging-cost savings and lower processing costs
- Value gains:
  - improved species mix
  - increased lumber-recovery factor
  - enhanced grade and dimension mix
  - increased residual chip values
- Risk reduction:
  - reduced insect and fire losses
  - less reliance on the open market for logs and for pulp chips
  - less risk of curtailed operations because of timber shortages

*Figure 2. Forest-level benefits from intensive management.*

The first item in Figure 2 is as far as many analysts have ever carried their benefit-cost arithmetic. They have simply estimated the increase in harvest volumes as a result of planting and other treatments, and applied this volume to a stumpage value projected ahead for 80 to 100 years or more. This usually gives negative or very meager rates of return on the basis of a conservative bias in estimates of both growth and value.

It does not take long to realize that moving stands forward in the harvest queue, the second item in Figure 2, can make stands operable 10 to 20 years earlier. This results in the "allowable-cut effect", that is, an increase in volume that is likely to be substantially above what may be achieved by Item 1. This is enormously important to communities that rely on a company threatened with curtailed operations as a result of wood shortages. Although it may not be possible to offset entirely the impending timber deficit in the short run, an important level of mitigation should be realized.

The remainder of Figure 2 requires little explanation. If you have any doubts about the legitimacy of this approach, then I recommend that you talk to foresters in Scandinavia, or to the more progressive firms in Canada and the United States. Even though the merits of intensive silviculture may still be disputed by academics or isolated public forest managers, you can rest assured that these people are part of a shrinking minority.

In the longer run, I hold the strong conviction that our national wood-supply target should be a minimum of 400 million $m^3$ by the year 2050. The major problem we face in this regard is that no agency in Canada has been motivated to project non-timber values along a similar time line. A quick look at Table 2 will underline this point.

Table 2. A new vision of forest stewardship for Canada.

| | 1950 | 1989 | 2050 | Percent growth[a] |
|---|---|---|---|---|
| *Annual harvest* (million $m^3$) | | | | |
| Softwood | 69 | 173 | 350 | 1.16 |
| Hardwood | 5 | 13 | 50 | 2.23 |
| Total | 74 | 186 | 400 | 1.26 |
| *Annual harvest/use* | | | | |
| Fish | ? | ? | ? | 1–3? |
| Wildlife | ? | ? | ? | |
| Recreation | ? | ? | ? | |
| Wilderness | ? | ? | ? | |

[a] per annum percent growth in annual harvest or use

Before moving on, there are some propositions that I would like to record for the critics. First, economic-efficiency criteria, as applied in standard net-present-value calculations, will continue to represent valuable tools for the forester in certain situations. Do not imply that I have thrown away my interest-rate tables. Second, microeconomic analysis is essentially concerned with contemporary calculations of the short-term interests of the firm, and in a restricted local situation.Microeconomics was never intended to serve as the sole or even principal guide for decisionmakers overseeing large areas of public land over long periods of time. Third, conservationist criteria are a vital part of the strategic thinking of senior officials and elected politicians, who have the fundamental responsibility to perceive clearly the intergenerational impact of public policies.

So much for a contemporary view of silvicultural investments. It really deserves more complete treatment than it was given here, and the forthcoming publication (Reed and Baskerville 1991) will perhaps do more justice to the case for intensive forestry than is possible in this short space.

## THE CENTRAL ISSUE

My attention was recently drawn to a couple of editorials written in 1881 for the *Bystander* by Goldwin Smith, a Toronto publisher. Smith deplored the irresponsible treatment of our forests, and asserted that the greatest threat was not the "prodigal use of the axe". The same could be said of the chainsaw today. The chainsaw is not the central villain in the piece. Smith went on to say this: "If the *Bystander* were now addressing the Canadian public for the last time, our parting word would be 'Conserve the Forests'."

The plea for conservation and wise use is not new, but is in fact very apt for today. So, I repeat an earlier line in order to underscore this truth: The central issue of forest policy for this decade is stewardship of forest land, not wilderness, not biodiversity and not clearcutting. And it is not land use *per se*. Diligent management of the forest resources must come first. If we do that well, then by definition both the size and quality of the forest-resources pie are going to be enhanced. It is nothing short of absurd to assume that the resource is fixed or declining. I say "absurd" because this philosophy closes our minds to the very attractive economic development options that intensive management offers. Equally important, believing the assertion closes off vital options for sustaining and enhancing the environment. If it is not true that our forests can be enhanced, then sustainable development is nothing short of a cruel joke.

In the final analysis, however, the challenge is clear. A prudent investment in forest stewardship will vastly improve our range of choices. And it might very well reduce the resource conflicts to a fraction of what they are today.

## CONCLUDING COMMENTS

All of the foregoing evidence and argument ought to drive the forest community into a new and fresh approach at strategic planning. The sequence of tasks as I see them is set out in Table 3. There is simply no excuse for muddling along, or for claiming that the "bottom line" prevents us from devoting time to the "top line", which is the resource base.

Table 3. A framework for strategic thinking.

- Recognize societal values
- Crystallize a vision
- Declare a policy ("This is what we intend to do.")
- Set targets and priorities
- Calculate the costs and benefits
- Establish accountability for results
- Implement the plan
- Monitor the plan and upgrade it regularly

Finally, the implications of this talk carry us in several directions. The most important is that our silviculture budgets are badly skewed towards planting. Unless we can correct this by securing *new* funds for intensive silviculture, the industry and its dependent communities are in for a bleak period of retrenchment. I choose to believe such a course would be a sorry betrayal of our custodial responsibilities. Stewardship is everyone's business.

This is a time for visionary thinking, or as Carl Sandburg has stated so well,

**"Nothing happens, unless first a dream."**

So I invite you to approach your task with realism and objectivity. At the same time, I invite you to dream of a better life as well as a richer life.

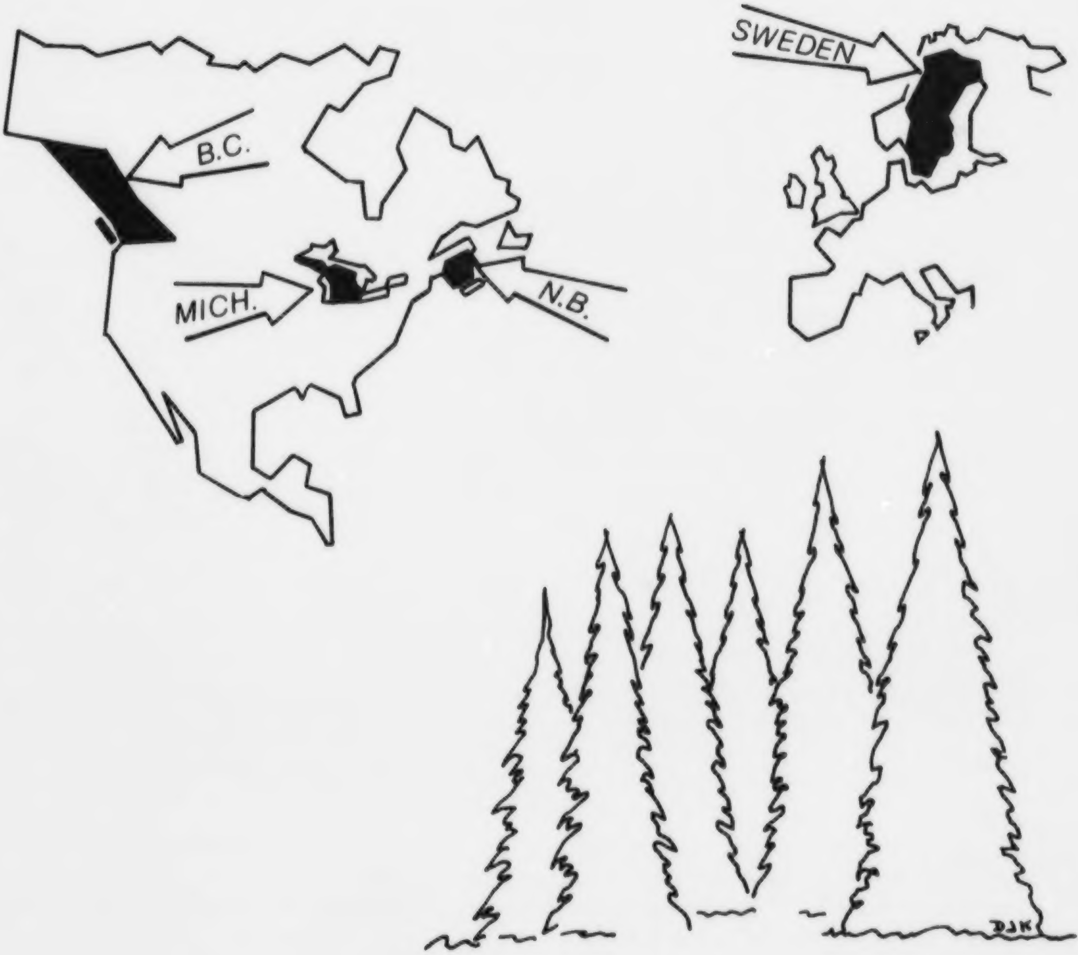
## LITERATURE CITED

Reed, F.L.C. 1989. Coping with the threats to Canada's softwood timber supply. Univ. British Columbia, For. Econ. Policy Res. Unit, Vancouver, B.C. FEPA Newsletter 4(2):3–4.

Reed, F.L.C. 1990. A vision of forest resources stewardship for British Columbians. Submission to the B.C. For. Resour. Commission. 15 May 1990, Vancouver, B.C. 9 p.

Reed, F.L.C. and Baskerville, G. 1991. A contemporary perspective on silviculture investments. Univ. British Columbia, Vancouver. J. Bus. Admin. 35 p. (in press)

# SESSION I
## *What is Being Done Outside Ontario?*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# SPACING AND THINNING IN SWEDEN

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## ABSTRACT

Spacing and thinning are long-established silvicultural treatments in Swedish and Scandinavian silviculture. In particular, thinning has been widely used throughout this century and today is normally performed two to four times during a rotation. In this paper, the role of these silvicultural treatments in Swedish forestry is discussed and a brief discussion of research into spacing and thinning is presented.

## RÉSUMÉ

L'espacement et l'éclaircie sont des traitements sylvicoles établis depuis longtemps en sylviculture suédoise et scandinave. L'éclaircie, en particulier, a été largement utilisée au cours de ce siècle, et de nos jours elle est pratiquée habituellement 2 à 4 fois au cours d'une rotation. Ce rapport aborde le rôle de ces traitements sylvicoles dans la foresterie suédoise et présente une brève analyse de la recherche sur l'espacement et l'éclaircie.

## THE ROLE OF SPACING IN SWEDISH FORESTRY

Spacing has been an important activity in Swedish silviculture since the early 1950s. At that time, large areas had been regenerated after what is commonly referred to as a "dark period" in Swedish forestry. During this "dark period", the primary forestry activity was harvesting commercial timber by high-grading or other cutting methods resembling it. These cuttings were often called "selection cuttings" in an attempt to justify the practice. Foresters hoped that the areas would regenerate naturally, and for this reason little effort was made to restock the cutovers.

About 1950, clearcutting, followed by natural regeneration from seed trees in Scots pine (*Pinus sylvestris* L.) or planting of either pine or Norway spruce (*Picea abies* [L.] Karst.), came into vogue. In these regenerated areas, particularly in successful, dense, naturally regenerated pine stands, spacing became essential for normal stand development. Stand tending soon became a well established and widely used treatment.

Currently, the majority of cutovers in Sweden are regenerated by planting. The role of precommercial thinning has therefore changed somewhat. The main objective now is to reduce the number of deciduous trees, primarily birch (*Betula* spp.). Hence, "cleaning" would perhaps be a better term. True spacing, however, is still important and widely used in naturally regenerated Scots pine.

## RESEARCH ON SPACING

A large number of spacing experiments were established to clarify the impact of spacing on stand development. This was done to provide practical forestry information on the effectiveness of spacing, and as a measure to persuade foresters to space their stands. Results from these experiments were summarized by Andersson (1974). One experiment was established in a dense, naturally regenerated stand of Scots pine. The number of stems exceeded 10,000/ha before spacing, which had been performed at a mean height of 3 m in a 14-year-old stand. Figure 1 shows the growth performance of the stand 15 years after spacing. The left side shows the numbers of stems greater than one of three specified diameter limits for each of the five spacing intensities; on the right side, corresponding volumes are given. With the removal of the smallest trees, it became evident that the plots with the lowest number of stems yielded the most volume. The mean diameters of trees at the five different spacings are 12.5, 11.4, 9.6, 8.4 and 5.3 cm, respectively, for densities of 1,800, 2,500, 4,000, 6,000 and 10,000 stems/ha.

Spacing, particularly in Scots pine, affects branch diameter and therefore the future quality of the sawtimber harvested. Figure 2 shows the number of trees for which the largest branch in the butt log is less than 20 mm thick, based on a sampling of 1000 of the largest trees from each of five levels of spacing. As shown, the number of potentially high-quality trees is significantly less when there are fewer than 4000 stems/ha.

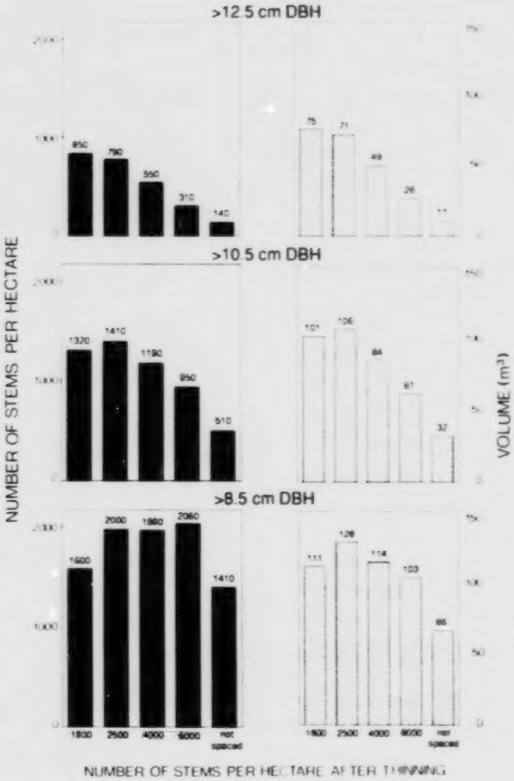

*Figure 1. Growth performance in spacing experiment 970 in Scots pine, central Sweden (60°N, 16°E). Number of stems (left column) and volume (right column) over three diameter limits. Trees were 29 years old at the time of measurement, and spacing was performed at 3 m height. (From Andersson 1974).*

If the spacing had been carried out earlier, at 1.5 m in height, for instance, diameter development would have been faster at the denser spacings, but the quality would have been poorer in the more open spacings.

## THINNING IN SWEDISH FORESTRY

Sweden's oldest thinning experiments were established in 1906 and some of them are still being monitored. Thinning has provided and is still providing a significant percentage of the roundwood harvested from Swedish forests. About 15 million m$^3$ is currently being harvested annually from 200,000 ha and thinning provides around 25% of this harvest (Fig. 3). During the 1950s and early 1960s, thinnings comprised more than 50% of the total harvest, but this has decreased rapidly since then. The state of Sweden's forests had changed over time; our old and middle-aged stands had been thinned several times and most of them were now understocked. This resulted in reduced growth and the need for further thinning was curtailed. Because of "selection cutting" from 1920 to 1950, very few areas needed to be regenerated. As such, very few young stands of first-thinning age had developed. The economic basis for thinning was poor due to low timber prices and, above all, the rapidly increasing cost of labor. Labor-intensive tasks such as spacing and thinning were affected significantly.

By the end of the 1960s, these problems had led many Swedish foresters to question whether thinning had any future in Swedish forestry. Row and line thinnings, forest management without thinnings, and the use of short rotations were discussed. However, the concept of "geometric thinning" was never applied to any measurable extent. Forestry without thinnings became more interesting and, in the late 1960s, two of the larger Swedish

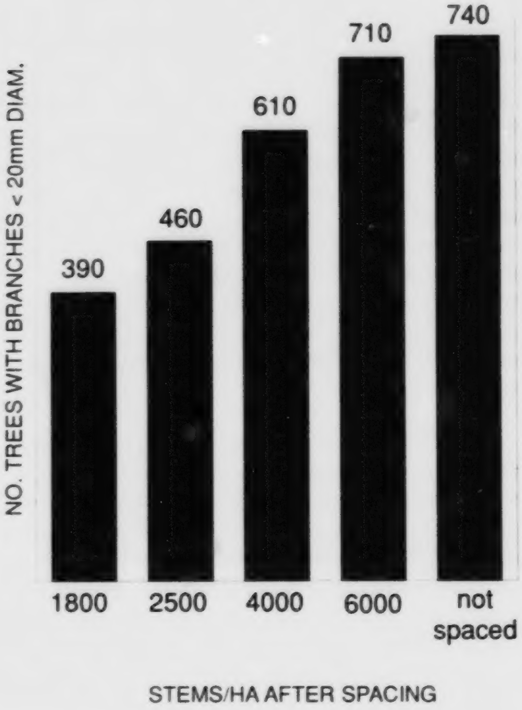

*Figure 2. Spacing experiment 970 in Scots pine, central Sweden (60°N, 16°E). Number of trees out of the 1000 largest whose thickest branch in the butt log is < 20 mm, at five different spacings. Trees were 29 years old, and spacing was performed at 3 m height. (From Andersson 1974).*

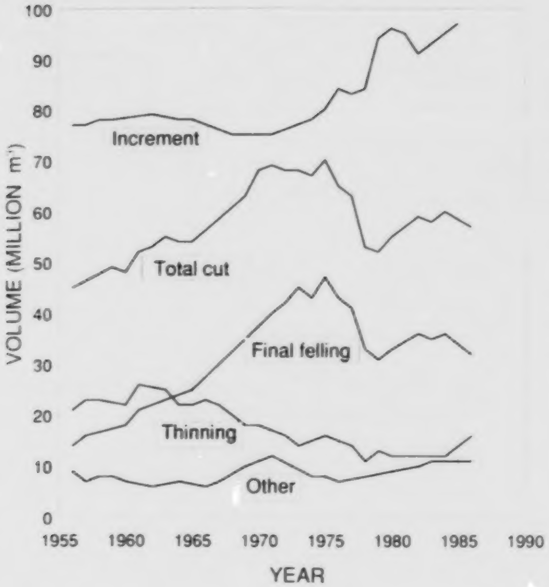

*Figure 3. Annual increment, total cut, and harvest in thinning and final felling in Swedish forests from 1956 to 1986 (data from the National Forest Survey).*

forest companies launched management strategies for subsequent wide initial spacing in plantations and no thinning. This program also included heavy spacing operations in established regenerated areas, in which the density of some stands was decreased to between 1,000 and 1,400 stems/ha. This was considered very low by Swedish standards.

Since then, the trend has changed and the volume harvested from thinnings has increased slightly during the 1980s (Fig. 3). This increase will undoubtedly continue. In northern Sweden especially, there occur vast areas of young stands, established in the 1950s, that are reaching the age for first thinning. These stands are often quite dense and will require thinning two or three times during the rotation.

Timber prices have increased, improving the economics of thinning. The costs of harvesting have been significantly reduced through mechanization. In the large forest companies, about 70% of thinnings are presently carried out using fully mechanized methods. By the mid-1980s, the development of harvesters had reached a level at which the machines could do a good job of thinning from a silvicultural point of view. During the early phase of mechanized thinning, most of the equipment used had been developed for final fellings, and being too large and heavy, frequently caused unacceptable damage to the residual trees. With smaller, better-adapted equipment, the damage to trees and soil has been reduced to a silviculturally acceptable level.

The combination of necessity and improved economy have markedly changed the attitudes towards thinning in Sweden, particularly in large-scale forestry operations. The attitude of the private forest owners (who own about 50% of the forest land) towards thinning has been more stable and optimistic throughout the difficult period in the 1970s. One obvious reason for this difference is that many of the private owners do most of the work in their forest themselves.

## NEW THINNING EXPERIMENTS

At the beginning of the 1960s, the Department of Growth and Yield at the College of Forestry (now the Faculty of Forestry) realized the need for a new series of thinning experiments. In the old experiments, thinnings had been light to moderate, and frequent (usually once every 5 years); this differed from the newer practice, a trend towards fewer and heavier thinnings. In the new series of thinning and fertilization experiments, traditional and very heavy thinnings were both tried. Thinning from above, which had not been tried experimentally before in Sweden, was also included. The plan included four full experiments (one in each of the four regions of Sweden) with 10 to 12 replications in both Norway spruce and Scots pine stands. The number of treatments varied from seven to nine, depending on the tree species and the region. The series of experiments is, however, incomplete for Norway spruce because of a lack of suitable stands in northern Sweden.

In Table 1 (Norway spruce) and Table 2 (Scots pine), results obtained over the first 15 years as a result of different thinning regimes are shown. During the first period after thinning, growth was slightly higher in the thinned Norway spruce plots (Table 1). This effect is well known and is caused by changes in stem form and in the distribution of increment over time. Over the first 15 years, the increment in all thinned plots was slightly below that of the control, but the differences were generally very small, except for the 70% thinning. It is surprising that thinning from above has done so well, with growth being 6% below that of the low thinning at the same intensity. The difference is statistically significant at the 5% level, but is less than was expected.

To give a more detailed idea of how the different thinning programmes affected a stand, data from one of the Norway spruce experimental plots in southern Sweden

Table 1. Relative volume increment 7 and 15 years after thinning Norway spruce in southern Sweden (data from Andersson [1980], Eriksson [1989][a]).

| Treatment | Number of thinnings | Removal at first thinning | Relative vol. incr. during the first 7 years | Relative vol. incr. during the first 15 years |
|---|---|---|---|---|
| Control | – | – | 100 | 100 |
| Low thinning | 6 | 20% | 107 | 96 |
| | 3 | 40% | 109 | 95 |
| | 1 | 70% | 80 | 73 |
| High thinning (from above) | 6 | 20% | 96 | 90 |
| Low thinning (extra heavy) | 6 | 40% | 105 | 92 |

[a] Eriksson, H. 1989. Hur har det gått med höggallringen? Unpublished paper, Swedish Univ. Agric. Sci., Dep. For. Yield Res., Garpenberg, Sweden.

(Lipit No. 921, Vallasen; 56°N, 13°E) are provided in Table 3. The original stand, with a density of 3500 to 4000 stems/ha, was first thinned at 30 years. In this plot, four out of the six planned thinnings have been carried out and the table shows the situation in the different plots immediately after the fourth thinning, 21 years after the first thinning. The control is outperforming any of the treatments, but this could be because the control may have had an ideal density (2130 stems/ha). Perhaps the density in the various thinning treatments is too low.

Table 2. Relative volume increment 7 and 15 years after thinning Scots pine in southern Sweden (from Andersson [1980], Eriksson [1989][a]).

| Treatment | Number of thinnings | Removal at first thinning | Relative vol. incr. during the first 7 years | Relative vol. incr. during the first 15 years |
|---|---|---|---|---|
| Control | – | – | 100 | 100 |
| Low thinning | 4 | 25% | 91 | 90 |
| | 2 | 43% | 79 | 81 |
| | 1 | 63% | 71 | 69 |
| High thinning (from above) | 4 | 20% | 87 | 86 |
| Low thinning (extra heavy) | 4 | 50% | 77 | 75 |

[a] Eriksson, H. 1989. Hur har det gått med höggallringen? Unpublished paper, Swedish Univ. Agric. Sci., Dep. For. Yield Res., Garpenberg, Sweden.

The results from the Scots pine plots in southern Sweden are shown in Table 2. The treatments are basically the same as for Norway spruce, with minor differences in the thinning intensity and the number of thinnings. The results, however, differ markedly from those in Norway spruce. The increment of all thinned plots has been 10 to 30% lower than for the unthinned control, and is inversely related to the intensity of removal in thinnings. The most surprising and interesting result is the good growth that resulted from thinning from above. The differences as a result of thinning from below are very small (ca. 4%) and not statistically significant. This result is indeed unexpected since thinning from above, particularly in Scots pine, was thought to be more or less disastrous with respect to the future development of the stand.

From these results, Norway spruce stands can sustain a reduction in standing volume of as much as 40 to 50% without reducing the current increment significantly. In contrast, any thinning in Scots pine will reduce the increment of the stand, with the reduction being proportional to the removal of basal area. The relationship between relative volume increment and relative basal area (unthinned controls = 100) after the first thinning in Scots pine and Norway spruce is shown in Figure 4. When comparing these results with the reaction of other tree species in European thinning trials, Eriksson (1989)[2] concluded that the general response of Norway spruce and Scots pine to thinning seems to be similar to that of shade-tolerant and shade-intolerant tree species, respectively.

## SPACING, THINNING AND THE FORESTRY ACT

Many aspects of spacing and thinning are strictly outlined in the Swedish Forestry Act. To avoid attack by bark beetles after spacing, Scots pine with a diameter of more than 7 cm at stump height can only be spaced between mid-May and mid-July. Norway spruce should be spaced in August or September. Very strict regulations have also been placed on the maximum amount of felled trees and "forgotten" logs left after thinning or on the area clearcut in an attempt to reduce the risk of beetle attack.

There are also limits on minimum and maximum stem number (at a 3-m height). Stands below the lower limit (less than 500 to 1,150 stems/ha, depending on site index and tree species) should be cut down and replaced by replanting. Stands above the upper limit are to be spaced or cleaned if deciduous trees are abundant.

With respect to thinning, the upper limits for the number of stems at certain top heights are stated and upper and lower limits are given for basal area. The state of the remaining stand must meet certain qualifications in other respects, namely which trees are selected (thinning from above is not allowed); the number of trees wounded during the operation (no more than 5%); the depth of wheel tracks in strip roads; and the extent of strip roads in relation to the total area of the stand.

Table 3. Results after the fourth thinning of 49-year-old, 23-m-high Norway spruce.

| Treatment | Number of thinnings | Removal at first thinning | DBH (cm) | Stem number | Basal area (m²/ha) | Volume (m³/ha) | Current increm. (m³/ha/yr) |
|---|---|---|---|---|---|---|---|
| Control | – | – | 18 | 2130 | 54 | 552 | 20.6 |
| Low thinning | 6 | 20% | 24 | 700 | 32 | 352 | 16.7 |
| | 3 | 40% | 27 | 600 | 34 | 375 | 17.8 |
| | 1 | 70% | 29 | 560 | 37 | 366 | 15.7 |
| High thinning (from above) | 6 | 20% | 14 | 1810 | 29 | 268 | 17.7 |
| Low thinning | 6 | 40% | 30 | 360 | 25 | 269 | 17.3 |

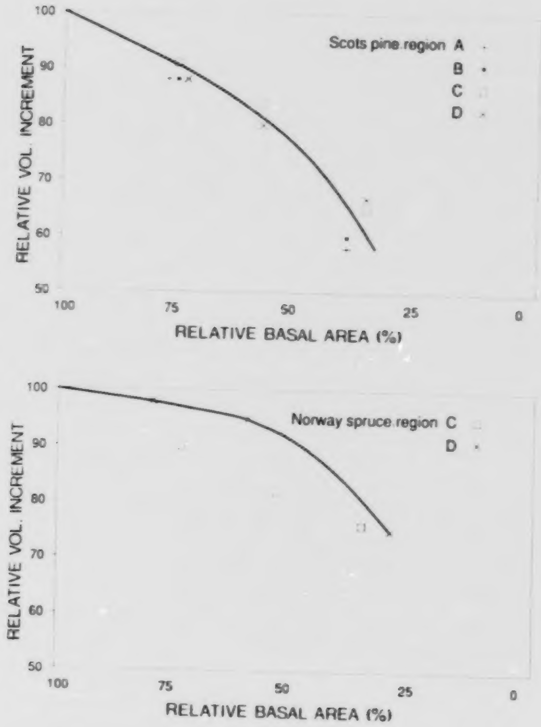

*Figure 4. Relative volume and basal area increment after first thinnings in Scots pine and Norway Spruce (data from Eriksson 1989[2]). Regions: A = northwestern Sweden, B = northeastern Sweden, C = central Sweden, D = southern Sweden.*

## CONCLUSIONS

Swedish views on thinning have shifted considerably over the past four decades and the ideas in vogue at any one time seem to have generally reflected the economics of Swedish forestry and particularly the economics of thinning. Although the future will undoubtedly bring good as well as bad times to Swedish forestry, I am personally convinced that thinning and spacing will continue to be important activities in Swedish forestry. If these treatments were eliminated, we would give up our ability to influence the future yield of our forests once regeneration is established. We would also be denied the ability to change species composition in stands, select future crop trees of good quality, promote diameter development and harvest wood that would otherwise be lost to natural thinning (i.e., mortality). We cannot afford to leave out the option of directing stand development towards our goal — a mature forest that produces a high yield of valuable timber.

## LITERATURE CITED

Andersson, S-O. 1974: Något on röjningens inverkan på beståndets gagnvirkesproduktion och kvalitet i barrskog. Royal Coll. For., Dep. For. Yield Res., Stockholm, Sweden. Res. Notes Nr. 33.

Andersson, S-O. 1980: Volume increment and stand safety in different types of thinning. p. 260–268 *in* H. Kramer, *Ed.* Biologische, technische und wirtschaftliche aspekte der jungbestandspflege. Schriften aus der Forstlichen Fakultät der Universität Göttingen, Band 67.

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[2] Eriksson, H. 1989: Hur har det gått med höggallringen? Unpublished paper, Swedish Univ. Agric. Sci., Dep. For. Yield Res., Garpenberg, Sweden.

# JUVENILE SPACING IN THE SUB-BOREAL SPRUCE BIOGEOCLIMATIC REGION OF BRITISH COLUMBIA

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## ABSTRACT

This paper discusses the juvenile spacing program in British Columbia with specific reference to the sub-boreal spruce (SBS) biogeoclimatic zone. Of all the biogeoclimatic zones in British Columbia in which juvenile spacing has been conducted, the SBS zone is the most similar to the situation in northern Ontario. This paper briefly outlines the background to forest management in British Columbia, the rationale for a juvenile spacing program, biological considerations and possible methods of juvenile spacing. Future challenges associated with juvenile spacing in British Columbia are listed.

## RÉSUMÉ

L'auteur discute du programme mis sur pied en Colombie-Britannique pour l'espacement des jeunes peuplements, en faisant spécifiquement référence à la zone biogéoclimatique subboréale à l'épinette. De toutes les zones biogéoclimatiques de la Colombie-Britannique où le programme a été réalisé, celle-ci ressemble le plus au nord de l'Ontario. L'auteur traite rapidement de l'historique de l'aménagement forestier en Colombie-Britannique, des motifs du programme, des aspects biologiques et des méthodes possibles d'espacement des jeunes peuplements. Il énumère les défis qui découlent de l'espacement des jeunes peuplements en Colombie-Britannique et que réserve l'avenir.

## FOREST MANAGEMENT IN BRITISH COLUMBIA

Unlike Ontario, British Columbia, especially the interior, is founded on a softwood sawlog economy with a pulpwood byproduct. The continuance of the sawlog economy is a driving force in the development of a comprehensive juvenile spacing program.

The forest industry is the province's principal economic generator: it contributes $13 billion annually to the provincial economy and more than $600 million in revenues each year to the provincial government; it produces 60% of Canada's lumber and provides 39% of the world's total exports of softwood lumber; it provides 90,000 direct jobs and an estimated 180,000 indirect jobs for British Columbians; and it accounts for 50% of every dollar of manufactured shipments. Our forests and rangelands also support a cattle industry and wildlife, with associated guiding, outfitting and viewing industries. Forests contribute directly and indirectly to the expanding recreation and tourism industries.

The British Columbia Ministry of Forests (BCMF) has stewardship responsibilities over all "provincial forests" — this includes encouraging the maximization of productivity, and managing and protecting the Crown's forest and range resources and other resource values to provide maximum benefits to all British Columbians.

Table 1 gives a breakdown of the different classes of forest land in the Province of British Columbia (Anon. 1990a). The 22.6 million ha of provincial forest land available and suitable for timber harvesting generates an annual allowable cut of approximately 75 million m$^3$.

The new 1987 Forest Act made it a legal requirement to prepare a pre-harvest plan of silvicultural action for all harvested areas. This plan prescribes how an area will be reforested and when it should attain the "free growing" standard. There are severe penalties for operators who fail to meet the objectives of the reforestation plan, such as a reduction in annual allowable cut and/or being charged double for any reforestation work that the government must undertake to meet the plan's objectives.

Table 1. Forest land statistics for the Province of British Columbia (data from Anon. 1990a).

| Land type | Area (ha) | Percent of total |
|---|---|---|
| Total area | 94,800,000 | 100.00 |
| Crown land | 86,400,000 | 91.14 |
| Provincial forests[a] | 80,700,000 | 85.13 |
| Productive forest land | 43,300,000 | 45.68 |
| Accessible productive forest | 22,600,000 | 23.84 |
| Avg. annual area harvested (1978-1988) | 238,969 | 0.25 |

[a] "Provincial forests" comprise 73.8 million ha in timber supply areas, and 6.9 million ha in tree-farm licenses.

Today, we in British Columbia are replanting 65% of all harvested areas and managing for natural regeneration on the remaining 35% (Anon. 1990b). By the end of 1990, we will have planted 300 million seedlings. During 1987, our turnaround year in reforestation, we planted more area than was harvested. We are now planting as much land as is harvested. In 1989, the cumulative number of planted seedlings passed the two billion mark, and should exceed three billion in 1992. The 1985–1990 federal–provincial Forest Resource Development Agreement (FRDA) provided major assistance in achieving this milestone. By the end of this agreement, the amount of "not satisfactorily restocked" (NSR) backlog was reduced by about 35%. Our province has now adopted the objective of reforesting all accessible operable backlog NSR areas by the year 2000.

## THE SUB-BOREAL SPRUCE ZONE

The climate of the Sub-boreal Spruce (SBS) zone is continental, and is characterized by seasonal extremes of temperature: there are severe, snowy winters; relatively warm, moist and short summers; and relatively low annual precipitation. In contrast to the boreal zone, the sub-boreal climate is less continental, and thus is slightly warmer in January and cooler in July. Sub-boreal winters are shorter and the growing season is slightly longer, with lower evapotranspiration in some cases.

Lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) is a fire-origin species, and occurs over much of the SBS zone. It is a major component of seral stands. The zone's fire history has resulted in extensive stands of overstocked lodgepole pine, on which the juvenile spacing program has concentrated. Operational spacing began in earnest in coastal British Columbia in the early 1970s, with the rest of the province following suit in the latter part of the decade. The economic conditions of the early 1980s meant that the program proceeded rather slowly until the creation of the 5-year cost-shared Canada–B.C. Forest Resource Development Agreement. Although the agreement was targeted at "backlog" reforestation, a major program of intensive silviculture was initiated. About 65,000 ha of juvenile spacing and 47,100 ha of aerial fertilization were completed (Anon. 1990c). In the SBS zone, 16,400 ha of juvenile spacing and 14,300 ha of associated fertilization has been carried out in lodgepole pine stands under this program. The BCMF historical records indicate that more than 165,000 ha have been spaced in the province to date, with approximately 34,000 ha of this in the SBS zone.

## WHAT IS JUVENILE SPACING?

Juvenile spacing is the reduction of density in young stands in order to control stocking, prevent stagnation and improve crop-tree quality (Anon. 1990d). Juvenile spacing allows the growth rate of residual trees to be maintained or increased. Species composition is changed and the rotation length is reduced through the selection of the leave trees. Different leave-tree densities may be prescribed at the time of spacing depending on wood production objectives and whether any subsequent entries for commercial thinning are planned. Precommercial thinning and "waste" thinning are other, more internationally used terms included in this category. A project is currently classed as juvenile spacing when the majority of cut trees are not merchantable.

## WHY SPACE TO GROW?

Spacing can be used to obtain any number of forest management objectives (Table 2).

Table 2. Reasons to space.

- reorganize growing space
- release selected crop trees
- salvage nearly stagnant stands
- "clean" stands
- control or adjust species composition
- reduce losses to insects, disease, etc.
- produce more uniform sizes
- reduce final harvest costs
- reduce milling costs
- reduce rotation length
- improve age-class distribution
- increase merchantable volume
- increase product value
- evaluate different management options
- reduce long-term fire hazard
- improve range for domestic animals (e.g., cattle) and wildlife
- improve recreational access
- improve water yield

The economy of the B.C. Interior is based on a softwood sawlog industry, for which a continuing wood supply must be available. Fire-origin lodgepole pine stands and some naturally regenerated stands are overstocked. Spacing can help to solve the problem associated with overstocking and can assure that many of the abovementioned forest management objectives are met.

The effect of stand density at an age of 20 years on height, diameter at breast height (DBH, outside bark) and volume at 80 years is illustrated in Figures 1–3, respectively (Anon. 1989). Johnstone (1985) found that very high densities resulted in reduced tree size, yield and value when stem density increased from 4,000 to 10,000 stems/ha. Average stand height was more than 3 m lower at the highest density (Fig. 1). Similarly, DBH decreased by at least 5 cm over the same density range (Fig. 2).

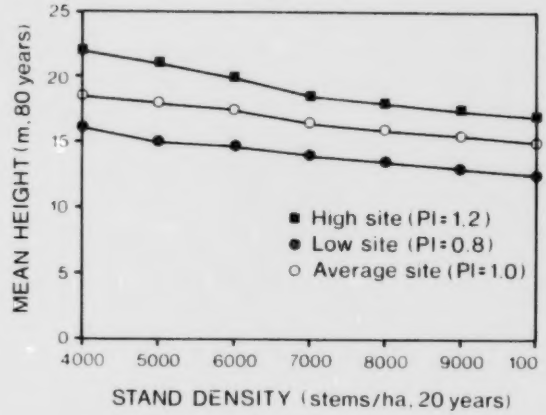

*Figure 1. The effect of stand density on mean height for all trees with DBH ≥ 1–5 cm.*

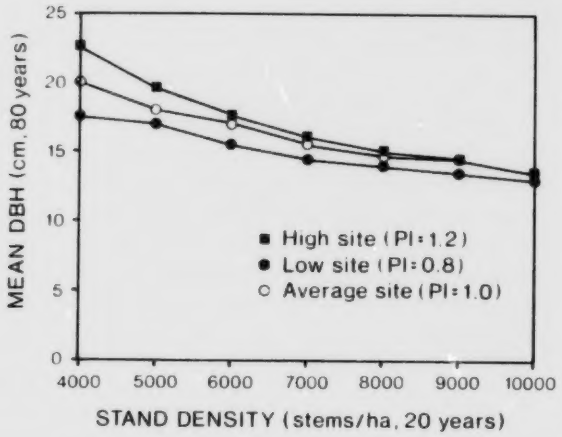

*Figure 2. The effect of stand density on mean DBH for all trees with DBH ≥ 1–5 cm.*

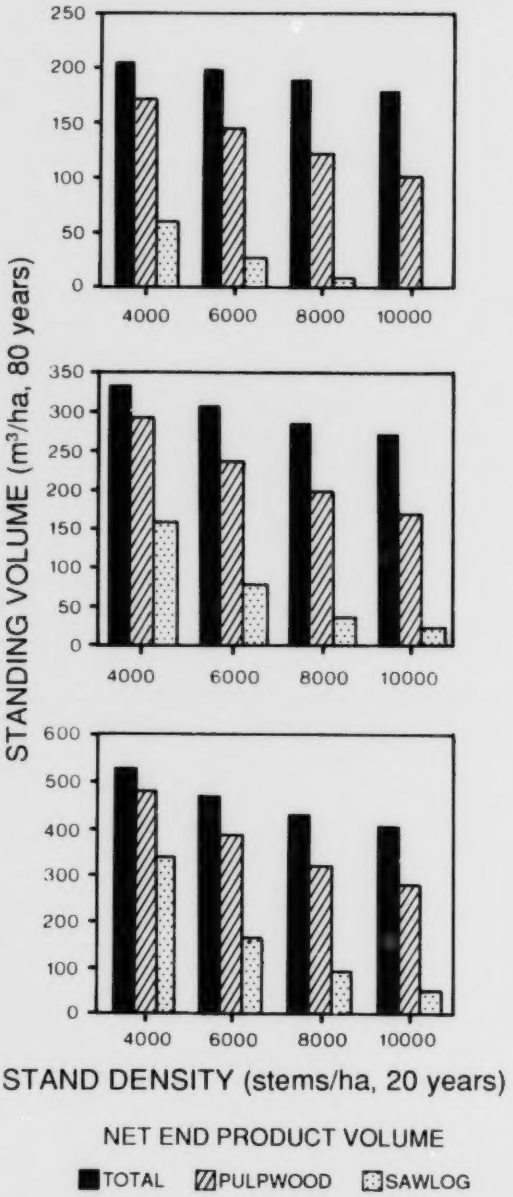

*Figure 3. Effect of stand density at 20 years on standing volume at 80 years. (pulpwood = 4.6-in. DBH, 4-in. inside-bark diameter at top, 1-ft. stump; sawlog = 8.6-in. DBH, 6-in. inside-bark diameter at top, 1-ft. stump; total = all trees, including stumps and tops.)*

Excessive stand density in a naturally regenerated, unmanaged lodgepole pine stand (16 m, at an age of 50 years measured at breast height) on an average site had a severe impact on net sawlog volume. In unmanaged natural stands with 6,000 stems/ha, net sawlog volume can be more than 50% less than in similar stands with 4,000 stems/ha. As a rule of thumb, net sawlog volume decreases by at least 50% for each additional 2,000 stems/ha above 4,000 (Fig. 3) (Anon. 1989).

As can be seen from Figure 3, the pulpwood, sawlog and total volumes all decrease with increasing density. As well, the relative percentage reduction of total volume increases as site index increases; that is, the effect is more pronounced on better sites.

Unfortunately, Johnstone's (1985) research was conducted in stands with stem densities greater than 4,000 stems/ha. From his data, it is impossible to determine the impact of stand density on merchantable volume, average stand height, and average DBH for lower stem densities.

For practical purposes, all sites in the SBS zone are of average or better quality. To ensure that sawlogs can be produced, spacing is obviously needed. With the passage of the 1987 Forest Act and the accompanying new silviculture regulations, juvenile spacing became a basic requirement for all timber licences. Areas that are overstocked with either interior lodgepole pine or Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) *must* be spaced. The maximum density for lodgepole pine, for example, relates to the licencee's obligation to ensure that a stand's density is low enough, without additional density control, to reach the minimum management objective within 100 years on good or medium sites, and within 140 years on poor sites. The maximum density for a given site type is presently being determined and is expected to be established by the fall of 1990. This legislative requirement is expected to produce an annual requirement for 12,000 to 15,000 ha of juvenile spacing in the SBS zone.

## WHEN TO SPACE

In general, selective juvenile spacing in lodgepole pine should be undertaken when the stand is between 10 and 30 years old and between 2 and 10 m tall. The earliest thinning should occur when crown closure has occurred and the live crowns are lifting from the ground. This permits the workers to cut the trees below the live crown. The recommended latest age to space occurs when there is only 25 to 30% live crown remaining.

## SPACING METHODS

Methods used for spacing may be (1) manual, using a wide range of tools including power-saws, brush saws and clippers; (2) manual, applying chemicals to individual trees; (3) by means of chemicals; (4) mechanized chopping, mulching, brushing, or slashing; or (5) combinations of these methods (Anon. 1990d).

### Hand Tools

Hand tools used in juvenile spacing include clippers or shears, the North Star tree girdler, Sandvik brush axes, and brush hooks. The application of hand tools is usually limited by the maximum diameter of the trees to be cut. Shears work well in high-density stands with trees less than 5 cm in diameter at stump height and with a high proportion of live crown. The North Star girdler has been used successfully to treat coastal Douglas-fir, hemlock (*Tsuga* spp.), alder (*Alnus* spp.) and interior lodgepole pine where stem diameter is between 3 and 13 cm. The main advantage of some hand-tool methods is that they are relatively inexpensive, safe and simple (compared with the use of power tools) and, as such, require little worker training or experience. However, axes and Sandviks are not recommended, as they present safety problems, are difficult to swing in dense stands, and are incapable of getting around and under slash to remove all the live crown. The other hand tools are well suited to projects aimed at using labor that might be unskilled in the use of power saws. However, a consistent level of supervision and training in tree selection and crew control is mandatory. The major disadvantages have been the relatively low productivity per person-day and high costs.

### Power Tools

Brush saws and chainsaws are the primary manual power tools used in spacing and thinning. Of the two, the chainsaw has been used most extensively and has become the most common tool in juvenile spacing. This is due to its wide range of applicability under varying conditions, its availability and ease of servicing, and its broad usage throughout the forest industry and general public. The major disadvantage of the chainsaw is that it requires a great deal of skill and care to be used safely. Of all the methods used in juvenile spacing, the chainsaw method is probably the most dangerous. Chainsaws require skill for efficient use and must be maintained in peak operating condition; they should not be used by inexperienced workers.

Use of the brush saw is generally limited to stands in which the maximum stump-height diameter of trees is less than 10 cm. They are most effective where ground conditions and slope do not impede worker access. Steep slopes, heavy ground debris and elevated slash or windfall are the most limiting site factors. The brush saw is considered an excellent treatment method for young, even-aged stands in the Interior, particularly logged and naturally regenerated stands or burned sites free of snags and debris. Under ideal conditions, the brush saw is considered the most productive method for single-tree-selection juvenile spacing. It is also a considerably safer tool to use than a chainsaw.

The major disadvantages of the brush saw, other than its limited application, are its high cost (about twice that of a comparable chain saw) and the level of skill required of the operator.

### Chemicals

The most common chemical method used in juvenile spacing is known as "hack and squirt". The tree to be killed is partially girdled with a hatchet and a systemic herbicide (e.g., MSMA, Glyphosate) is injected into the wound. This method is best suited to stands with densities of 2,000 to 4,000 stems/ha in which the average diameter exceeds 6 cm DBH and the trees are branch-free to at least the height of a forest worker (i.e., approximately 1.5 m).

With "hack and squirt", the trees are left standing, thereby reducing the heavy slash accumulations often associated with spacing in older stands. This reduces the fire hazard and can improve access through the treated stand. Depending on herbicide cost, chemical spacing by a trained crew is most cost effective in stands in which movement between trees is easy (i.e., low density, larger diameters). The treated trees can also provide some shelter or protection for the crop trees from windthrow, sunscald, etc.

The major disadvantage of the method is that it is difficult for the supervisor and crew to see the effects of their work, as no physical change occurs in the stand and the crew does not gain a sense of accomplishment. As well, quality control is nonexistant, as it is easy to miss trees that should have been treated.

### Machines

In an effort to improve the economics of spacing in dense, immature stands, several mechanical methods have been developed and tested. Three machine types have been considered: (1) a rubber-tired or tracked skidder with a front-mounted rotary cutting head (e.g., Hydro-Ax, Kershaw Klearway), (2) a crawler tractor with a front-mounted blade, and (3) a crawler tractor pulling a drum chopper or crusher (e.g., the Marden chopper).

With mechanized spacing, the goal has been to clear, mulch, crush or otherwise destroy standing material in alternating rows, producing a pattern of parallel strips. As well, if machine clearing is done at right angles to the initial pass, then a checkerboard pattern is formed, increasing the area exposed to the edge effect, in which the trees on the edges of the leave strips or clumps respond to the increased light and growing space afforded by this release. Ideally, dense, even-crowned, healthy, pure stands are best suited to this technique. The application of mechanized spacing is restricted by slope, roughness of terrain (e.g., gullies), soil texture and moisture content, and the presence of ground obstructions (e.g., large slash, stumps, boulders, etc.).

Machine spacing results in low costs per unit area (in relation to manual spacing) and lends itself to easy supervision once the residual strip width is established. In addition, fire hazard can be significantly reduced through the mulching of debris if rotary-type machines are used. Spacing machines are ideally suited for use in isolated areas.

A primary disadvantage of mechanized spacing is the lack of crop-tree selectivity. Even in very dense stands, the trees that exhibit superior diameter and height growth would not necessarily be left as crop trees when complete strips are being cleared. Even if only the edge trees are being considered for crop trees, release is only on one side; hence, growth response is reduced. Many non-crop trees within the residual strip will also respond to the treatment at the expense of the edge trees. Great care must be taken to avoid damage to trees in the residual strip. In young stands, with live crowns that extend to the ground, lower branches may be left alive and able to compete with crop trees for nutrients and moisture.

A more feasible approach, both biologically and economically, may be a combination of mechanical and manual spacing. Access in very dense stands can be improved by strip-spacing with a spacing machine. The residual strips can then be selectively spaced with hand tools, power tools or chemicals. The overall cost of this type of treatment is lower than that of a purely selective type of treatment, but the response is expected to be nearly equal to that of selective spacing. The morale of the silvicultural worker would usually be higher and a contractor would find it easier to organize his crew in more open settings. With the combined approach, follow-up selective spacing need not be done immediately after the initial machine work. Increased slash deterioration, providing improved access, would occur. Stabilization of leave trees would occur and visible dominance could develop. However, the incidence of disease and damage in leave strips may require a more immediate follow-up.

## BIOLOGICAL CONSIDERATIONS

During the implementation of the lodgepole pine juvenile spacing program in the SBS zone, we quickly became aware that a number of biological considerations must be addressed. All have potentially significant negative impacts on juvenile spacing efforts.

Both the silvicultural planner and the juvenile-spacing worker must be able to identify the insects (e.g., Warren's collar weevil [*Hylobius warreni* Wood] and the terminal weevil [*Pissodes terminalis* Hopping]) and diseases (e.g., dwarf mistletoe [*Arceuthobium americanum* Nutt.], western gall rust [*Endocronartium harknessii* (J.P. Moore) Y. Hirats.] and Atropellis canker [*Atropellis piniphilia* Weir]) that can have a detrimental impact on crop trees. The ability to identify these impacts allows the planner to prepare an appropriate prescription and the spacing worker to implement this prescription properly.

Dr. T. P. Sullivan of the University of British Columbia's Department of Forest Sciences developed strategies for minimizing damage by snowshoe hares (*Lepus americanus* Erxleben), red squirrels (*Tamiasciurus* spp.) and porcupines (*Erenthizon dorsatum* Allen) for areas in which juvenile spacing is done (Sullivan 1990).

Certain climatic factors must be considered before undertaking juvenile spacing. Windthrow and snow breakage can be serious problems. It is advantageous to space stands early, before they become too tall, in an attempt to reduce the risk of these concerns. A second option for high-risk areas would be to consider a combined approach, mechanized strip spacing with the use of power tools delayed until crop trees are stabilized. One should avoid areas with known occurrences of heavy winds, heavy snows, and/or ice storms. Stands with less than 50% live crown should not be fertilized for at least 3 to 4 years after spacing; fertilizing too soon after spacing increases the risk of breakage by wind and snow.

Fire is a serious threat to any forest stand, but more so when considerable investment has been made. To date, only a few areas that have undergone juvenile spacing have been burned by wildfires. To minimize the risk of loss from fire, a number of factors must be considered during the pre-treatment, treatment and post-treatment phases of a juvenile spacing operation.

The pre-treatment phase allows the greatest number of options. One can even determine whether or not the project should proceed, remembering that there is a cost in non-treatment. There is a tremendous fire risk from recent spacing slash; however, the long-term risks for the area are lowered. At this stage, one has the opportunity to assess fire-risk maps, assess the fire frequency, and so on. Fire suppression and prevention capabilities can be planned accordingly. During the treatment phase, contractors are required to comply with all fire regulations and special patrols can be conducted in areas with the greatest fire hazard. At the post-treatment stage, there is an opportunity for road closures and special patrols as dictated by the fire hazard, but until the fire hazard diminishes, one must live with the decisions made. It should be noted that forest fertilization lowers the risk of fire by enhancing "green-up" and microbial breakdown of spacing slash.

### Growth and Yield

Under the direct delivery component of the Canada–B.C. FRDA, a major increase in growth and yield research was conducted in British Columbia to augment the ongoing research program. In addition to the research effort, permanent growth and yield plots were established in operationally spaced and control stands, and the results were compared. I recommend that this approach be taken in all spacing and thinning programs. To properly plan and prioritize silvicultural programs, accurate growth and yield information is critical.

## IMPLEMENTATION OF JUVENILE SPACING

The juvenile spacing program in British Columbia started small and expanded as acceptance of the technique, realization of the need for it, and funding increased. Initially, a major effort was made to organize and educate local contractors through small training courses based on local slide and tape shows. Small contracts were then advertised and the program has grown continually. Juvenile spacing is labor intensive and, consequently, benefits every forest-based community. Not only are employment opportunities enhanced, but the productivity and quality of forest stands are improved significantly. I understand that a long-awaited program in spacing and thinning has just begun in Ontario. I encourage you to make use of the juvenile spacing section of the B.C. Silviculture Manual (Anon. 1990d, Chapter 9). Being somewhat familiar with your situation, I know that many of our approaches, contract clauses, reporting procedures, and so on, would be directly applicable to your situation. When our program in the Prince Rupert Forest Region began, we sent new staff to the Vancouver Region to observe their work. This approach helped us to implement our program very quickly. We are eager to offer the same opportunity to you.

## FUTURE CHALLENGES

The following challenges need to be addressed in British Columbia because of their impact on the juvenile spacing program. The challenges can be divided into two broad categories:

1. Challenges that affect the total silvicultural program, including spacing:

- to develop a provincial silvicultural stategy
- to manage biodiversity, including old-growth stands
- to improve growth and yield information
- to develop crop-planning techniques
- to increase public-information programs
- to develop licencee incentives for implementing intensive forest management programs
- to integrate timber management with wildlife objectives
- to finalize a new B.C.–Canada Forest Resource Development Agreement
- to develop strategies to address the timber-supply need
- to establish the silvicultural worker in the Canadian workplace
- to increase the use of non-clearcutting silvicultural systems.

2. Challenges specific to the spacing (space to grow) program:

- management of juvenile stands
- development of pruning and commercial thinning programs
- development of strategies for strategic forest-fertilization programs
- creation of incentives to encourage thinning and utilization of the products of thinnings.

## CONCLUSION

Remember that reductions in productivity as a result of excessive stand density must be compared with the cost of not spacing.

## LITERATURE CITED

Anon. 1989. Maximum density in lodgepole pine: discussion paper. British Columbia Min. For., Victoria, B.C. 24 p.

Anon. 1990a. Forest management in British Columbia. British Columbia Min. For., Victoria, B.C. 6 p.

Anon. 1990b. Reforestation: more than seven seedlings planted every second. British Columbia Min. For., Public Affairs Br., Victoria, B.C.

Anon. 1990c. Report on the final evaluation of the Canada – B.C. Forest Resource Development Agreement. Prepared by Touche Ross Inc. for For. Can., Pacific and Yukon Region, Victoria, B.C.

Anon. 1990d. Ministry of Forests silviculture manual. British Columbia Min. For., Tech. and Admin. Serv. Br., Victoria, B.C.

Johnstone, W.D. 1985. Thinning lodgepole pine. p. 253–262 *in* D.M. Baumgartner, R.G. Krebill, J.T. Arnott and G.F. Weetman, *Ed.* Proc. Symp. Lodgepole pine: the species and its management. 8–10 May 1984, Spokane, Wash. and 14–16 May 1984, Vancouver, B.C. Washington State Univ. Press, Pullman, Wash.

Sullivan, T.P. 1990. Reducing mammal damage to plantations and juvenile stands in young forests of British Columbia. For. Can., Pacific and Yukon Region, Victoria, B.C. FRDA Memo No. 153. 12 p.

# SPACING IN EASTERN CANADA: THE NEW BRUNSWICK EXPERIENCE

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## ABSTRACT

From a slow start in the late 1960s, spacing (precommercial thinning) in New Brunswick has matured into a versatile and widely used forest management tool. This paper highlights the development process and what has been learned from it, with special emphasis on operational aspects such as planning, equipment, labor and training.

## RÉSUMÉ

Après avoir démarré lentement dans les années 60, l'espacement (éclaircie précommerciale) est devenu un instrument de gestion forestière très polyvalent et est largement utilisé au Nouveau-Brunswick. L'auteur souligne l'évolution de la méthode et ce qu'on en a retiré, en mettant l'accent sur les aspects opérationnels comme la planification, le matériel, la main-d'œuvre et la formation.

## BACKGROUND

### Before 1975

The history of spacing (precommercial thinning) in New Brunswick is rather short. Before the mid-1960s, there was no organized spacing conducted on Crown forest lands. On small, private forest lands (private woodlots) owners were advised of the benefits of thinning by the Provincial Forest Extension Service, but no significant areas were treated.

During the 1968–1975 period, the province tested several different manual, motorized manual and mechanized spacing systems. A number of test plots with different spacing ratios (distance between residual trees) were established. In general terms, these studies have shown that after 10 years, the best *individual* tree growth was obtained with a 3.6- x 3.6-m spacing. The best *total* stand growth was obtained for 2.4- x 2.4-m or 2.7- x 2.7-m spacings; stands that were spaced at 1.5 x 1.5 m and 1.8 x 1.8 m showed signs of suppression.

### 1975 to the present

A turning point occurred in 1975, when a federal–provincial forestry agreement was signed. With funds from the agreement, the province hired SwedForest Consulting to do a demonstration project. Six stands in different parts of the province, with very different stand conditions, were treated by an experienced crew using modern spacing saws. In terms of technique used, production and planning, the SwedForest project provided a benchmark from which the province could start. A few of the comments in this report have their origin in this particular project.

The availability of agreement funds, creation of the new Forest Extension Service and slowly increasing interest among woodlot owners resulted in the introduction of spacing and the spacing saw in the woodlot sector. In the beginning, it was basically a question of "show and tell". I still vividly remember the first field day in the Edmunston Panhandle area, when some 35 local woodlot owners, in pouring rain, heard, saw, and in some instances even tried, the spacing saw. I was the missionary and the demonstrator, all in one soaking-wet person. This field day also represented the beginning of active "hands on" involvement by the Forest Extension Service, both in the field of spacing and in the development of educational aids for training staff and woodlot owners.

## MOTIVES FOR SPACING

Spacing is a management tool that, depending on the goals, can permit the forest manager to:

- shorten the *rotation period* of a stand;
- increase the volume growth of *individual trees*; and
- increase the merchantable growth of *stands.*

On Crown lands, a predicted wood shortage "kick started" the use of spacing as a means to make stands harvestable earlier than if no spacing had been applied. Planting alone cannot influence wood supply in the 20 to

40 years remaining before the shortages develop; spacing can. The introduction of the modern spacing saw and an abundance of suitable natural regeneration further fueled the process.

In the woodlot sector, the availability of agreement funds provided a strong incentive to conduct spacing. The activity is also considered environmentally soft compared with a radical site preparation and planting operation.

For both Crown and private lands, cost is a concern. Renewing a stand by means of natural regeneration and spacing costs about half of what a similar operation with site preparation, planting and plantation tending costs.

## WHAT HAVE WE LEARNED?

### Management Considerations

Spacing is not an end in itself. It is an efficient tool to achieve management goals. By using growth models with the ability to predict the effect of spacing under different stand conditions, today's manager can decide when, where and how much spacing is required to meet or set goals.

It is important that stand selection criteria clearly reflect management goals, making it possible for the manager to select the most suitable stands in terms of site quality, species, age and location. These criteria will then have to be translated further into operational guidelines, spelling out the desired species mix, the number of stems per hectare left, and so on.

### Biology/Operations

If the use of natural regeneration is a management priority, the choice of harvesting technology must be done with the goal of minimal damage to advanced regeneration. Harvest instructions should include removal of *all* mature trees in *one* operation to minimize damage. Leaving big residual hardwoods should especially be avoided. If these hardwoods are felled *before* spacing, they create a major problem for the crew moving around in the stand. If they are felled after, the stand is usually damaged.

The spacing saw is more efficient in stands with small-diameter trees and every effort should be made to create such stands when the harvest is carried out.

### Workers

Efficient and high-quality spacing work requires well-trained and motivated operators as well as qualified supervisors. It takes about one work season to reach a consistently high level of quality and productivity. Employers should try to develop a work force based on trained operators who do this type of work year after year. Spacing is not an appropriate task for casual labor with high turnover rates.

The attitude of the worker plays a major role. It is important that the operator not only knows *how* to do the job but also *why* it is done so that he or she can take pride in the work.

Previous work experience with a chainsaw has often proven advantageous, since the operator can better appreciate the upright work position required.

### Training

Proper training is the most important factor in increasing both production and quality of work. All available experience supports this statement and most of the problems experienced in the East over the years can be linked to insufficient training of operators and/or planners and supervisors. It is important that, when large-scale spacing operations are introduced in a region, the training resources are developed at the same time.

There are several potential sources of training. On the provincial level, community colleges can provide institutional and mobile training. In some instances, there are private local consultants who can hold training sessions. Equipment manufacturers such as Husqvarna/Electrolux have a special training department that can train workers and/or instructors. Finally, the industry and forest extension services can develop training resources. Teacher/instructor training should preferably be done through a Ranger School or be contracted out.

In New Brunswick, substantial efforts were made to put together suitable educational aids such as 16-mm film, videos, pamphlets, etc. Some were developed "in house", others were obtained from saw manufacturers, research organizations and other extension services. The material has been extensively and successfully used in training. Annual refresher courses are strongly recommended.

### Equipment/Maintenance

There is no substitute for a professional spacing saw for the spacing of stands with small-dimension trees in terms of production, work safety and ergonomics. A chainsaw is simply not suitable or desirable.

Regular basic maintenance (air filter, proper setting, etc.) is important to provide high motor performance, which in turn is crucial for high productivity. A spacing saw does not have extra power to compensate for poor maintenance. By comparison, a harvesting worker can purchase a bigger chainsaw than required to be sure of sufficient power.

The number one maintenance item is proper blade filing. This aspect is often overlooked, and reduced production and excessive motor wear result.

### Work Technique/Methods/Safety

Quality as well as quantity and safety should be the production goal for spacing and the selection of suitable stands is a key factor. Larger sites should be divided into blocks, permitting separation of operators. Two operators should *never* work side by side for safety reasons.

The most important components of the work technique are *directional felling* and working in a swath 2 to 3 m wide. The saw should always be applied so that the cut tree falls in the desired direction, i.e., out into the cleared area.

If the weather is windy, the operator should choose a swath in which the wind will push the tree in the desired direction. The operator should also work *along* slopes, not up and down.

Finally, never leave a green branch on a balsam fir; doing so will enable the remaining branch to develop into a tree.

### Miscellaneous

When spacing is introduced into an organization as a management tool, it is important that the managers be well aware and supportive of the activity and that they understand its potential, its requirements and its limitations. It is equally important, especially during the introductory period in the field, that the supervisors involved are knowledgeable both in planning and laying out the operation. They must also be aware of correct work techniques and safety so that they can correct and advise operators. Training the supervisors before starting up is very important.

In the initial stages in New Brunswick, the Forest Extension Service and the chainsaw manfacturer (Husqvarna) developed a partnership that proved to be very beneficial. Husqvarna provided traveling instructors annually and the Forest Extension Service organized provincial workshops and field days. Industry, woodlot-owner groups, federal and provincial agencies and educational institutions participated. These annual sessions became a successful continuing-education vehicle that covered all aspects of spacing and associated activities.

### Looking Ahead

Looking into the future is always difficult, but a few trends are visible. On public forest land, spacing is an accepted, proven management tool for forest renewal. We will see increased use of joint planting/spacing forest-renewal prescriptions that reflect the conditions on harvested areas, especially with respect to natural regeneration. We will probably see the introduction of some mechanized methods, but the spacing saw will remain the major tool.

Training will be developed further and become widely accepted as one of the key contributing factors to successful operations on public and private (woodlot) forest land. We will see the development of qualified, well trained silviculture contractors and workers, including women and Native people. We will see more standardized approaches, perhaps even the development of a national standard for training and eventually certification of silviculture workers.

Eastern Canada congratulates the organizers of this seminar and wishes them luck in their efforts. If anything that we have learned or developed is of any help to you, please feel free to use it.

# STOCKING CONTROL IN MICHIGAN'S STATE FORESTS: A RECENT HISTORY

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## ABSTRACT

Increasing demand for timber products over the past two decades has led to intensified silviculture on State Forest lands in Michigan. Productivity has been improved in three major cover types — northern hardwoods, jack pine (*Pinus banksiana* Lamb.) and red pine (*P. resinosa* Ait.) — mainly by controlling stocking levels. Economic analyses have shown a positive rate of return for these silvicultural investments. Aspen (*Populus* spp.) may soon be added to the list of cover types routinely receiving stocking-control treatments.

## RÉSUMÉ

Au Michigan, la demande accrue de produits du bois au cours des deux dernières décennies s'est traduite par l'intensification des soins sylvicoles dans les terres forestières de l'État. On a amélioré la productivité de trois principaux types de couverts forestiers (feuillus du Nord, pins gris et pins rouges) grâce principalement à des programmes de surveillance du matériel relatif. Des analyses économiques ont révélé que les sommes investies dans ces programmes sylvicoles ont donné un taux de rendement positif. On ajoutera peut-être bientôt les peupliers (*Populus* spp.) à la liste de types de couverts faisant l'objet d'une surveillance courante du matériel relatif.

## INTRODUCTION

Michigan is often said to be the statistical leader for the Lake States in matters related to forests and forestry. I've never been certain what that means, but have taken it to mean that whenever something new appears, it's seen in Michigan first. This seems to hold true for most things — things as varied as market trends, stumpage prices and the gypsy moth (*Lymantria dispar* L.).

It seems likely that, in similar fashion, things that are happening in the Lake States may presage similar events in northern Ontario. For this reason, it may be of value for me to recount some of the happenings of the past 25 years or so in Michigan and how they have affected our operations. And, since time seems to be accelerating exponentially, there may be just about time to tell about it before it starts happening here. We think we're in the middle of a silvicultural revolution. I'll try to explain.

The Michigan Department of Natural Resources manages 1.5 million ha of State Forest land for timber, wildlife and recreation. Twenty-five years ago our system of timber management might have been appropriately described as passive: Most timber was sold in response to specific requests from loggers, although some was advertised for public auction. Statewide, we were producing nearly three times what we were able to harvest (Table 1).

Table 1. Growth and removal of forests on Michigan's commercial forest land (data from Chase et al. [1970] and Smith et al. [1986]).

| | Annual growth[a] | | Annual harvest[a] | |
|---|---|---|---|---|
| | million ft$^3$ | million m$^3$ | million ft$^3$ | million m$^3$ |
| 1965 | 580 | 16.41 | 206 | 5.83 |
| 1979 | 678 | 19.19 | 275 | 7.78 |
| 1986 | 753 | 21.31 | 398 | 11.26 |

[a] growth values in m$^3$ have been converted from values in ft$^3$ by the editors.

With timber falling down everywhere due to a lack of markets, we were usually overjoyed at the prospect of getting some cutting done. We'd go out and look, and if the desired timber was reasonably close to maturity, we'd write a permit for cutting. Our major concern was to design the cutting to favor regeneration. There was little danger of overcutting.

In the late 1960s, markets improved and the foresters began trying to take control. A forest inventory system was devised and implemented and management plans began to emerge. Markets improved to the point that most timber of reasonable quality that was reasonably accessible could be considered merchantable. An improvement over the old system of "hunting and gathering" was needed.

Foresters began to schedule cuttings instead of relying on loggers to find merchantable stands. If cuttings couldn't be accurately scheduled by year, at least a sequence could be prescribed based on relative stand condition.

This caused quite a stir at first. Loggers were dumbfounded to hear the forester say that a stand wasn't scheduled to be harvested for another 2 or 3 (or 10!) years (Fig. 1). Gradually, we made the change and moved one step away from hunting and gathering and closer to primitive silviculture.

Silviculture is similar to agriculture in many ways. As in agriculture, different crop species require different management techniques and crop yields are related directly to the cultural practices employed. Perhaps the biggest difference between silviculture and agriculture lies in the length of the crop rotation. Whereas the crop yield in agriculture may depend on practices employed a year before harvest, silvicultural yields are usually governed by practices that took place 50 or more years prior to harvest. Therefore, our ability to affect the quality of today's timber stands is severely limited. However, the work we do today does affect the nature of the stands we will have in the future. To put it another way, if we continue to do things the way we have in the past, we have little chance of ever improving on what we have now. We are trapped by our past practices unless we do something differently. To state it in yet another way, unless we change our direction, we're doomed to arrive where we're headed (Fig. 2).

In 1975, our agency received a special appropriation of $1 million to do something different — to invest in silviculture. We have received a similar annual appropriation since then.

## NORTHERN HARDWOODS

Our first priority was to do thinnings in northern hardwood stands. Most of our hardwoods were clearcut in the 1930s and we were left to work with the resultant second growth. The results of the thinnings were monitored by Michigan Technological University workers and showed an increase of 22% in annual diameter growth[1]. These cuttings were intended to reduce basal area to 16 m$^2$/ha. Results fell in a range of 16 to 20 m$^2$/ha. Diameter response was greatest at the lowest BA.

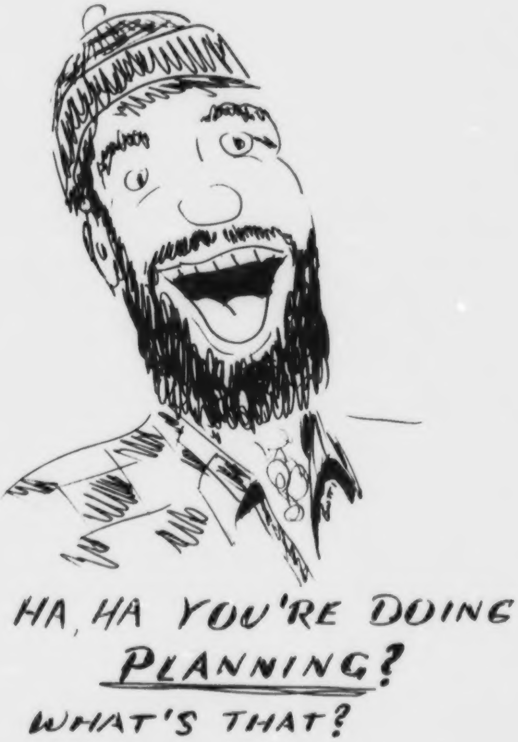
HA, HA YOU'RE DOING PLANNING?
WHAT'S THAT?

*Figure 1. Loggers were dumbfounded to hear us talk about schedules.*

Intuitively, some of us thought the forest would benefit from a heavier cut on that first entry into the stand. In 1972, we made one cut in a pole-sized stand to reduce basal area (BA) to 14, 16 and 20 m$^2$/ha for purposes of comparison. This was not a replicated study, so I won't give figures except to say that two things were evident in the most heavily cut stand: regeneration is well established and growing, and diameters have increased sufficiently that stand growth is now measurable in board-feet in the 14-m$^2$ plot, whereas trees in the other stands

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[1] Johnson, J.A. and Willis, G.L. 1978. Thinning effects on Michigan Department of Natural Resources cultivation program in pole-size northern hardwoods. Michigan Tech. Univ., Ford For. Center, L'Anse, Michigan; Wilson, D.W. 1981. The effects of thinning northern hardwood stands in Dickinson County, Michigan. Michigan Tech. Univ., Ford For. Center, L'Anse, Michigan. Unpubl. Rep.

FOREST
MGMT
POOR QUALITY
If we don't
CHANGE OUR
DIRECTION,
WERE DOOMED
TO ARRIVE
WHERE WERE HEADED!

*Figure 2. Linear thinking has its drawbacks.*

are still too small to meet sawlog specifications. Since that time, research results have substantiated our findings (Erdmann 1986).

Our economic analyses of these practices indicated a potential yield of more than 25% above inflation to be gained from thinning these hardwood stands (Murray 1990). We are now preparing to conduct a second thinning. The material to be removed will be merchantable in most cases — mostly pulpwood, but with some larger sawlog material also.

## JACK PINE

Once our hardwood thinning program was up and running, we turned our attention to softwoods, particularly jack pine (*Pinus banksiana* Lamb.). Markets were strong and regeneration was weak in some places. Examination of timber-sale records and discussions with field silviculturists indicated that planted stands yielded nearly twice the volume typically produced by natural stands. This can most likely be explained by the stocking control that resulted from planting at constant spacing, since superior seed sources were not used for the plantations we have harvested so far.

We rely on natural regeneration and direct seeding in many areas. A common problem with these methods is overstocking and we are experimenting with methods of mechanical thinning in areas of natural jack pine regeneration to counteract the effects of that overstocking. A 6-foot-wide (1.82 m) rolling chopper pulled behind a small skidder shows some promise in this regard (Nelson 1988).

## RED PINE

Ten years ago, markets began to appear for the red pine (*Pinus resinosa* Ait.) that had been widely planted across Michigan 30 years earlier. We now have markets for a range of products (posts, poles, pulpwood and sawlogs), but the highest value is for utility poles (Anon. 1990).

Examination of some spacing studies of red pine[2] showed that our then-current planting rate of 1360 trees/ha would not yield pole-quality material. Knot size and stem taper disqualified trees planted at the wider spacings (Fig. 3). This has also been found in Wisconsin (Laidly and Barse 1979). We have returned to a planting density of 2200 trees/ha because this increased density provides for a greater diversity of products in the future. If poles maintain their higher value, we will be doing well; if not, we'll have some very nice sawtimber to sell.

Our resident economist examined the economics of going back to a higher stocking. His conclusion was that a real rate of return (above inflation) of more than 4% can be realized[3] by planting red pine at a variety of densities from 1000 to 2700 trees/ha. A case can be made for planting only 500 to 1000 trees/ha (Lundgren 1981), but such a regime would produce no wood suitable for use as utility poles and would place that stand at greater risk of damage from the Saratoga spittlebug (*Aphrophora saratogensis* Fitch)[3].

For red pine, our first thinnings come at around 30 years of age. These are usually mechanical thinnings that remove every third row. Stocking is reduced to about 21

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[2] Barse, R.G. 1985. Red pine plantation density and methods of cutting study, Bosom Field replication, progress report. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Unpubl. Rep.

[3] Murray, R. 1990. Impacts of spacing on economic values in red pine and northern hardwoods. Mich. Dep. Nat. Resour., Lansing, Mich. Internal Commun.

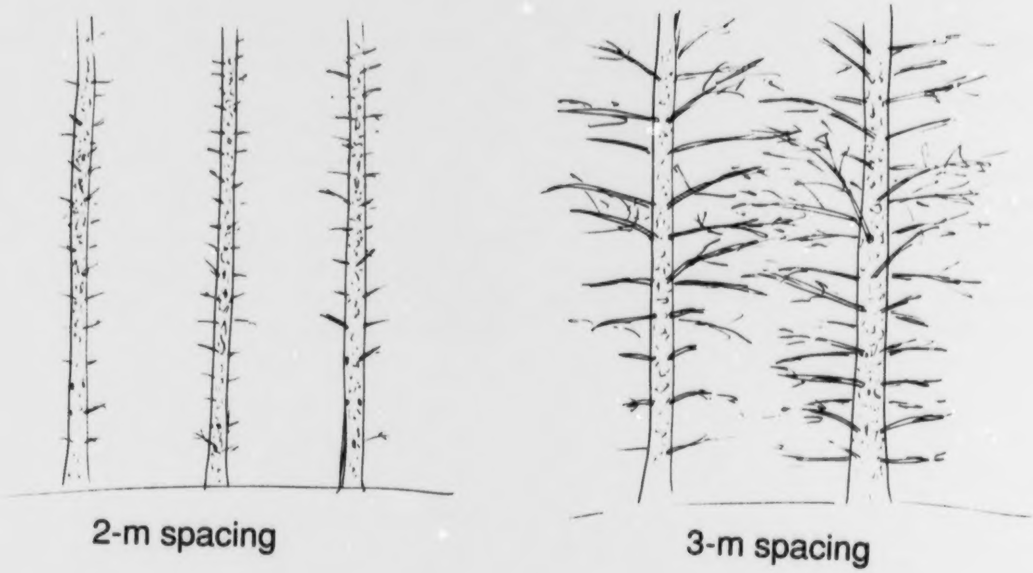

*Figure 3. Tree form of red pine planted at two spacings.*

$m^2$/ha in that first thinning and to 28 $m^2$/ha in subsequent thinnings. Again, documentation can be found to support lower stocking levels (Lundgren 1965), but we feel that the higher quality of the trees produced at these levels justifies the higher stocking.

However, if our planting survival brought stocking down to 800 to 900 trees/ha, we would accept that stocking rather than go to the added expense of replanting. In the case of planting, trees/ha is used in our prescriptions instead of BA because the trees are too small for BA measurements to be meaningful.

## ASPEN

Markets for aspen (*Populus* spp.) have expanded greatly in the Lake States in the past decade. The largely single-aged structure of this resource makes it necessary to harvest more than the sustainable level to avoid losing the cover type as a result of old age. One of the possibilities being stongly considered in Michigan is thinning in some young aspen stands to accelerate their development to merchantable diameters. This would help us fill in the gaps in the younger age classes.

## CONCLUSIONS

To complete the story, our silvicultural appropriation has not kept pace with inflation, while demands for timber and silvicultural needs have accelerated beyond the inflation rate. In spite of our silvicultural program, we're falling behind.

We have felt so strongly that the practices described above are sound investments that we have begun searching for ways to borrow money in order to continue. One of the major commercial banks in Detroit has worked with us and is ready to loan us $1.5 million (or more) per year for just about as long as we want to keep borrowing. We'll pay the loan back from our increased stumpage returns. Special enabling legislation has been written and is now about halfway through the legislative process.

These silvicultural practices pay off well in the future by providing better quality products faster than we are currently producing them. The process is not magic — it's simply a matter of providing space to grow.

## LITERATURE CITED

Anon. 1990. Average stumpage prices for: April 1989 — March 1990. Michigan Dep. Nat. Resour., For. Manage. Div., Lansing, Mich.

Chase, C.D., Pfeifer, R.E. and Spencer, J.S. 1970. The growing timber resource of Michigan 1966. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Resour. Bull. NC-9.

Erdmann, G.G. 1986. Methods of commercial thinning in even-aged northern hardwood stands. p.191–210 *in* R.D. Nyland, *Ed.* Proc. Symp. on Managing Northern Hardwoods. State Univ. New York, Coll. Environ. Sci. and For., Syracuse, N.Y., Fac. For. Misc. Publ. No. 13 (ESF 87–002).

Laidly, P.R. and Barse, R.G. 1979. Spacing affects knot surface in red pine plantations. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Res. Note NC–246.

Lundgren, A.L. 1965. Thinning red pine for high investment returns. USDA For. Serv., Lake States For. Exp. Stn., St. Paul, Minn. Res. Paper LS–18.

Lundgren, A.L. 1981. The effect of initial number of trees per acre and thinning densities on timber yields from red pine plantations in the Lakes States. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Res. Paper NC-193.

Nelson, M.K. 1988. Thinning jack pine with a rolling chopper. Michigan Dep. Nat. Resour., Lansing, Mich. For. Manage. Notes. Vol. 2.

Smith, B.W. and Hahn, J.T. 1986. Michigan's forest statistics, 1987: an inventory update. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Gen. Tech. Rep. NC–112.

# SESSION II

## *Spacing and Thinning in Ontario*

# OVERVIEW OF THINNING IN THE NORTHWESTERN REGION OF ONTARIO

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## ABSTRACT

Precommercial thinning as a management tool in Northwestern Region is presented in relation to stand- and forest-level decisions. Specific site features and regeneration options in the region combine to create conditions suitable for employing low-cost regeneration techniques, such as aerial seeding. Using these techniques in conjunction with precommercial thinning is a viable economic option on many sites in the region. Thinning may be directed to address potential wood-supply problems on certain forest management units and an example from one particular unit is used to illustrate this approach. The current level and potential magnitude of the thinning program in Northwestern Region are outlined.

## RÉSUMÉ

On traite l'éclaircie précommerciale dans la région du Nord-Ouest en relations avec les mesures d'aménagement concernant des peuplements ou des forêts entières. Certains caractères du site, conjugués aux possibilités de régénération dans la région, font que les conditions sont propices à l'utilisation de techniques de régénération peu coûteuses, comme l'éclaircie précommerciale. L'utilisation de ces techniques en combinaison avec l'éclaircie précommerciale est une option économiquement viable pour bon nombre de sites dans la région. L'éclaircie peut être réalisée de façon à résoudre d'éventuels problèmes de ressources en bois dans certaines unités de gestion forestière; pour expliquer cette approche, on prend l'une de ces unités comme exemple. On décrit le programme d'éclaircie actuellement en application dans la région du Nord-Ouest et l'envergure qu'il pourrait avoir.

## INTRODUCTION

In the Northwestern Region of the Ontario Ministry of Natural Resources (OMNR), seeding of jack pine (*Pinus banksiana* Lamb.) is a viable regeneration technique. Throughout the region, extensive areas have been regenerated to jack pine by aerial and natural seeding after man-made or natural disturbances. The success of aerial seeding has resulted in it becoming the predominant regeneration treatment in the area.

Figure 1 shows that direct seeding was the largest component of the total regeneration program in the region in 1988. In that year, seeding comprised 60% of the total regeneration effort. In addition, Northwestern Region has a high frequency of wildfires, a large portion of which result in regeneration from seed already on the site. For the 1971–1979 period, the region averaged 127,000 ha of wildfire per year, 70% of the provincial total (Brown 1984). For the 1980–1989 period, the regional average was 52,850 ha of wildfire per year (Fig. 2) (S. Reany-Iskra, OMNR, Northwestern Region, personal communication).

Regeneration by seed often results in successfully stocked stands, although stocking and density can be excessively high. Total seedling density varies among seeding techniques. The highest densities are generally associated with aerial seeding and seeding after wildfires. Young stands of jack pine originating from aerial seeding may contain up to 50,000 stems/ha, although densities of 7,000 to 15,000 stems/ha are more common. Density of fire-origin jack pine stands may exceed 100,000 trees/ha. At the highest densities, growth may slow when the stand is between 10 and 20 years old (Vassov and Baker 1988). Individual trees in dense natural stands are often thin-crowned and highly susceptible to ice and snow damage (Janas and Brand 1988). In addition to high stem densities, seeding often results in stands that are characterized by variable stocking and clumped stem distributions (Van Damme and McKee 1991).

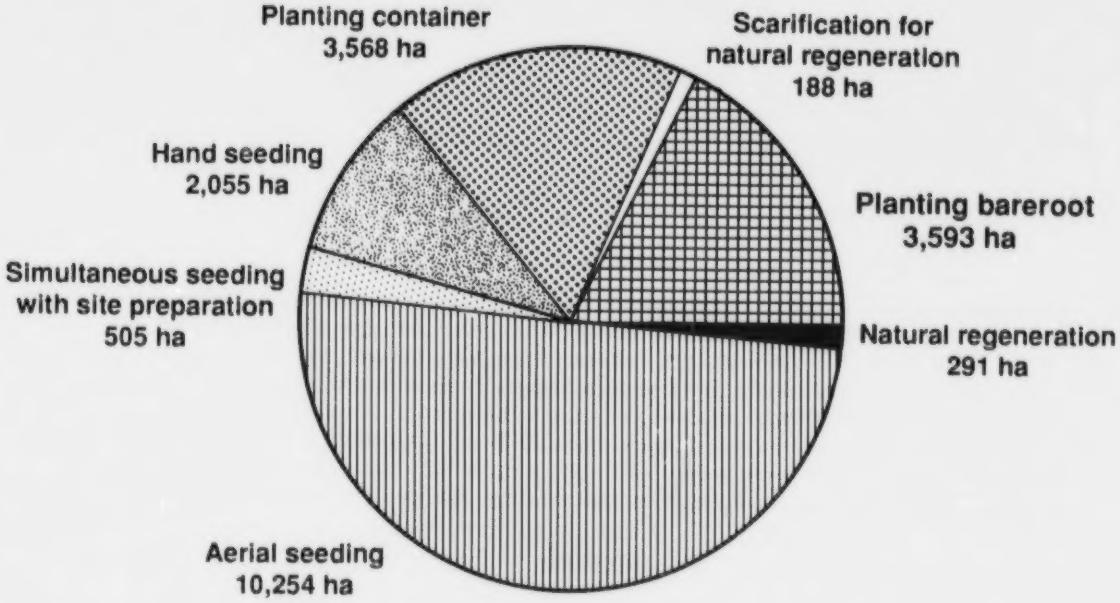

*Figure 1. The area regenerated by various treatments in 1988 in the Northwestern Region of Ontario.*

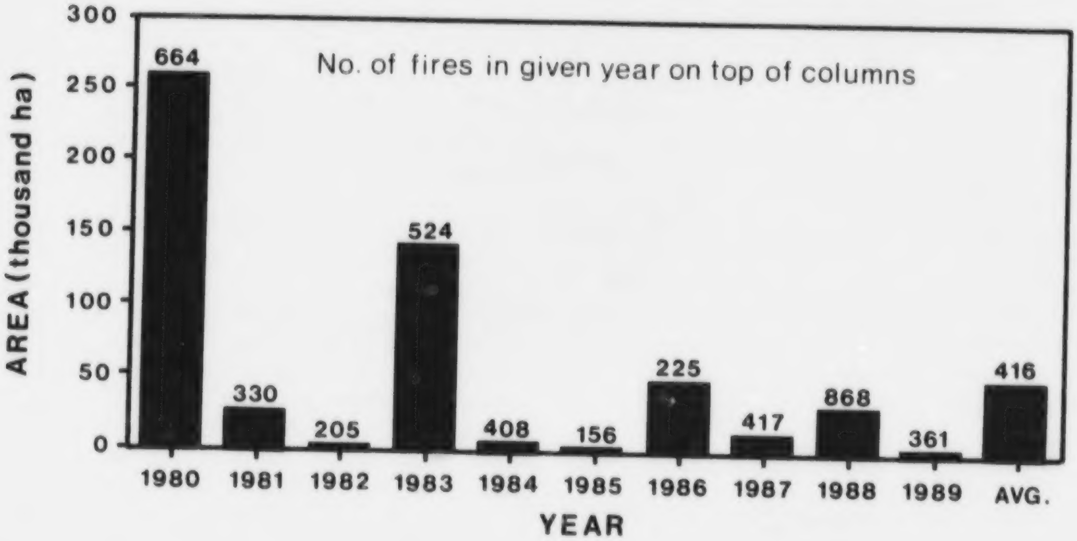

*Figure 2. Occurence of fire, and areas affected, from 1980 to 1989 in the Northwestern Region of Ontario.*

When the regenerating stand is not optimally stocked, some form of density or stocking control is considered. Since seeded areas lack the regular spacing common to planted stands, thinning should be considered as part of the management regime for stands regenerated by seed. The decision to use seeding as the stand-regeneration technique and precommercial thinning as the means of spacing control involves a number of stand- and forest-level considerations.

## STAND-LEVEL CONSIDERATIONS

### Site Features

On favorable sites, seeding as an artificial regeneration technique has been quite successful in Northwestern Region (B.W. Smith 1984). Sites selected for regeneration by means of aerial or natural seeding have generally been described as sites with less competition on which receptive seedbeds may be prepared (e.g., deep, sandy outwash and shallow, sandy tills) (Anon. 1986). A Forest Ecosystem Classification system has recently been published for Northwestern Ontario (Sims et al. 1989), and the vegetation and soil types described by this classification system may be amalgamated into various groupings for the purpose of developing management interpretations. As defined by this classification system, the "overview groupings" for which aerial seeding of jack pine is most often used comprise the following vegetation types:

- Jack pine/Feathermoss,
- Black spruce-Jack pine/Feathermoss,
- Jack pine-Black spruce/Blueberry/Lichen, and
- portions of the Jack pine/Shrub-rich type.

These groupings of vegetation and soil/site conditions generally represent dry, less fertile site conditions, for which very little shrub competition is expected (Fig. 3).

### Costs

On suitable sites, the benefit/cost ratio of seeding and precommercial thinning (to achieve spacing control) versus planting is favorable. A comparison of cost efficiencies for establishing jack pine stands was recently completed (Corbett 1989), in which three treatment regimens were compared: natural regeneration after wildfire, followed by precommercial thinning; artificial regeneration from aerial seeding, followed by precommercial thinning; and artificial regeneration from planting only. Establishing stands by aerial seeding with subsequent precommercial thinning for density control at year 10 was more cost efficient than using planting to achieve the same result (Fig. 4) (Corbett 1989). Of course, the treatments are not acceptable for all sites, but when options are available, aerial seeding/precommercial thinning is the more cost-efficient alternative. The greater investment efficiency of seeding and precommercial thinning is, in part, a result of the delayed cost of thinning when compared with planting (Vassov and Baker 1988).

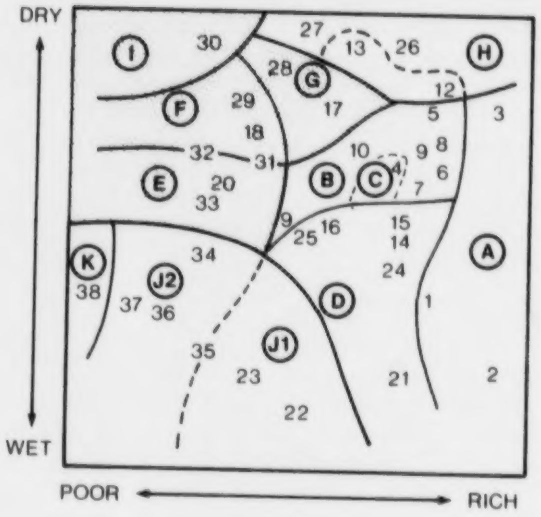

*Figure 3. Edaphic grid, highlighting Forest Ecosystem Classification vegetation and soil/site groupings for which seeding of jack pine is commonly prescribed (from Sims et al. 1989).*

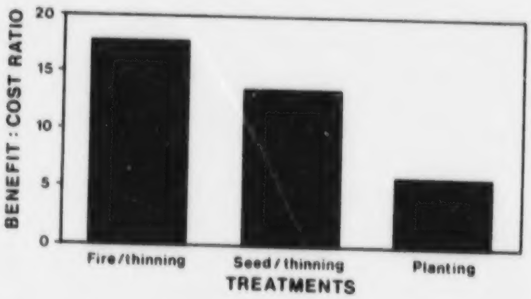

*Figure 4. Comparison of benefit/cost ratios for three silvicutural regimens (from Corbett [1989]).*

The cost factors associated with thinning influence the timing of the operation. By thinning at young stand ages (15 years or less), brush-clearing saws or sandviks may be used to remove the smaller-diameter trees, which results in considerable savings over removing larger material with chainsaws (Riley 1973). The cost of precommercial thinning with brush-clearing saws or sandviks generally ranges from $200 to $450 per hectare. The increased productivity and cost efficiency of the brush-clearing saw over the sandvik for thinning young stands has been demonstrated (Riley 1973). Generally, the presence of large rocks, stumps, scattered residuals, steep slopes and broken terrain preclude the use of machine-thinning in the region.

Precommercial thinning increases the cost efficiency of the final harvest. Immediately after precommercial thinning, the average diameter of the stand is increased because the smaller trees have been eliminated (the "chain-saw effect"). Precommercial thinning increases the diameter increment of these residual crop trees and, as a result, trees will be larger in diameter at rotation age. Harvesting larger trees at rotation age will result in an increase in harvest efficiency and a reduction in the costs of delivered wood.

### Growth Response

Vassov and Baker (1988) summarized information regarding the growth response of thinned jack pine. Thinned stands, when compared with unthinned controls, have demonstrated higher diameter increments, similar height growth, higher merchantable volume per hectare, lower mortality and increased stem taper.

High initial densities appear to be required to ensure good early growth and form of jack pine; however, this may result in a slowdown in growth early in the stand's development (Vassov and Baker 1988). Thinning allocates site resources to fewer stems and the residual trees experience an increased diameter increment (C.R. Smith 1984, Vassov and Baker 1988). Precommercial thinning in young stands also eliminates excess trees that would not reach merchantable size and thereby concentrates growth on the future crop trees. Young stands of jack pine respond more favorably to thinning and this response appears to diminish rapidly with age (Vassov and Baker 1988).

The benefits associated with precommercial thinning can only be properly calculated when reliable predictions of growth response and potential yield are available. Precommercial thinning trials have been established in the region to derive some local growth information, but the results of these investigations will not be available for a number of years.

### Spacing Prescriptions

Currently, when conducting precommercial thinning, forest managers in Northwestern Region tend to prescribe conservative spacing regimes that reflect their concern with the development of jack pine stem form at wider spacings. Spacing prescriptions are currently based on field observations, since there are no stand-density guidelines for prescribing post-thinning stand densities to meet specific management objectives. Stand-density guidelines have proven to be useful for prescribing thinning treatments in other jurisdictions (Reineke 1933, Drew and Flewelling 1979, McCarter and Long 1986). Similar models for jack pine in Ontario would assist forest managers in determining the thinning intensities required to meet specific product objectives (e.g., average stand diameters). Provincial models could be modified to reflect local conditions or other management considerations (Peterson and Hibbs 1989).

### Other Factors

Other factors must be evaluated by forest managers when a precommercial thinning program is being considered. Thinning may be used to select phenotypically superior crop trees and remove diseased trees or trees of poor vigor. Thinning may increase crop tree vigor by increasing the availability of soil moisture during the spring growing season (Janas and Brand 1988). On the other hand, it is suspected that opening the stand by thinning may promote the spread of Western gall rust (*Endocronartium harknessii* [J.P. Moore] Y. Hirats.) by creating favorable conditions for spore dispersal (Chong and Juzwik 1988). Damage by twig-boring insects may also increase as a result of increased populations in the slash of thinned stands (Vassov and Baker 1988). Opening the stand by thinning will increase the diversity of understory plant species and may increase the availability of browse for wildlife.

## FOREST-LEVEL CONSIDERATIONS

### Wood Supply

The use of precommercial thinning may address some of the future wood-supply concerns that have resulted from an unbalanced age-class distribution. When managing land for an industrial supply of forest products, it is important to maintain a continuity of wood supply to sustain an economic level of operations. An unbalanced age-class distribution may disrupt this continuity of wood supply. Precommercial thinning may be undertaken to decrease the impact of the potential supply gap on wood-using industries.

As mentioned, thinning accelerates the diameter growth rate of the residual trees. This response will reduce the time the stand will take to reach operable diameters and may be used to reduce the rotation age of the stand. C.R. Smith (1984) gave an example in which a reduction in the rotation age of about 10 years could be achieved by thinning the stand to a spacing of 1.6 m at 9 years. In this way, larger trees may be grown under shorter rotations.

Figure 5 gives an example of a management unit with an unbalanced age-class distribution and with age-class "gaps". This is a typical situation for many of the management units in the region. In the example, precommercial thinning in the 10–20 year age class should result in the thinned stands becoming harvestable at a younger

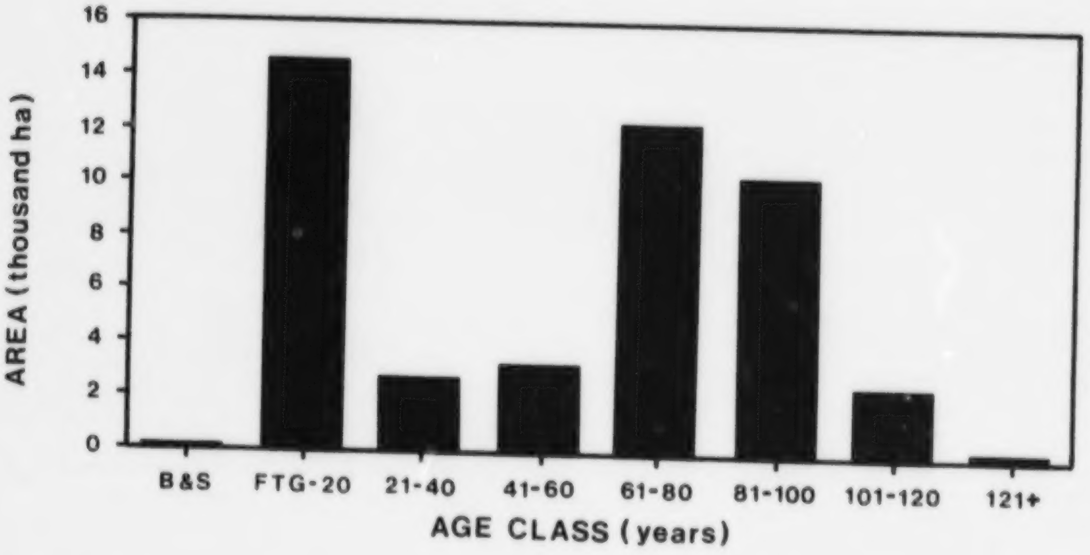

*Figure 5. The age-class distribution in the jack pine working group of the Dryden Crown Management Unit. (Source: 1991-2011 Timber Management Plan for the Dryden Crown Management Unit.)*

age. Thinned stands in this age class will reach operable diameter sooner and will assist in filling some of the wood-supply gaps apparent in the 21–40 year age class.

### Treatment Optimization

Silvicultural treatment options, including precommercial thinning, must be evaluated to optimize the investments required to meet forest-management objectives. Currently, the analysis of silvicultural treatment options in relation to biological and economic limitations is completed in an *ad hoc* manner. In the region, a number of tools are currently available, or are being developed, to assist forest managers with the complex analysis associated with the optimization of silvicultural treatments (Towill and White 1987, Wang et al. 1987, Towill et al. 1988, LeBlanc and Towill 1989, Sims et al. 1989, Bell et al. 1990, Willcocks et al. 1990). There is a tremendous opportunity for a substantial improvement in the sophistication of silvicultural treatment optimization over the next few years.

## CURRENT PROGRAM AND FUTURE OPPORTUNITIES

Although not all areas regenerated by seeding or disturbed by wildfire will require precommercial thinning, it is apparent that there is a large area in Northwestern Region in which this treatment may be suitable. Although the potential magnitude of the program is large, the application of this technique has been minimal to date. Figure 6 outlines the amount of precommercial thinning that has been conducted in the region over the last 10 years. One reason for the low level of precommercial thinning has been the uncertainty of obtaining funding to conduct a thinning program. However, an inspection of the planned level of precommercial thinning in the current 5-year timber management plans shows that an average of only 1850 ha/yr of this treatment is planned in the region, and approximately 1,600 ha of this total is scheduled in only one district. It is apparent that forest managers, faced with a limited silviculture budget, are currently selecting other silvicultural priorities for their units.

There is considerable opportunity for expansion of the precommercial thinning program in the region; however, given limited resources, decisions to thin existing stands may defer treatment of recent cutover areas. Analysis of these treatment options presents a major challenge for forest managers in Northwestern Region over the next few years. Wood-supply modeling techniques and the optimization of silvicultural-treatment models must be further developed to ensure that thinning efforts are strategically guided within the framework of the entire forest-management program.

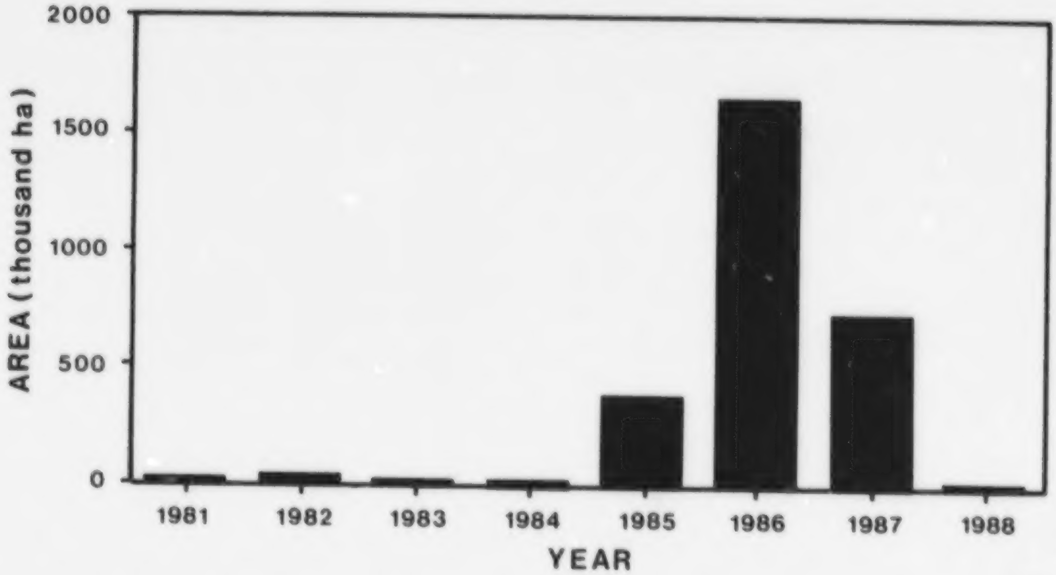

*Figure 6. The area of precommercial thinning in Northwestern Region, 1981-1988.*

## SUMMARY

The conditions in Northwestern Region have resulted in large areas of regeneration from aerial and natural seeding. Seeding may result in unacceptable stocking or density and may require precommercial thinning as a means of spacing control. The Forest Ecosystem Classification may be used to refine descriptions of sites suitable for various silvicultural options, including seeding and precommercial thinning. On suitable sites, seeding followed by precommercial thinning is a more cost-efficient method of stand establishment than planting. Precommercial thinning may be used to increase diameter growth, reduce rotation age and improve the continuity of wood supply. Improvements in the strategic application of precommercial thinning as a management tool would result from the development of stand-density guidelines and wood-supply modeling and treatment-optimization techniques.

## ACKNOWLEDGMENTS

We thank Messrs. Colin Bowling and Glen Niznowski for helpful suggestions resulting from their review of this paper, and Jim Mackenzie, Colin Blakemore and Shirley Syrja for technical assistance in preparing the document.

## LITERATURE CITED

Anon. 1986. Jack pine working group. Ont. Min. Nat. Resour., Toronto, Ont. Silvic. Guide Series.

Bell, F.W., Willcocks, A.J. and Kavanagh, J. 1990. Preliminary variable density yield tables for four Ontario conifers. Ont. Min. Nat. Resour., Northwestern Ont. For. Tech. Devel. Unit., Thunder Bay, Ont. Tech. Rep. 50. 80 p.

Brown, G. 1984. Aerial seeding of wildfire areas in the Northwestern Region. p. 93-101 *in* C.R. Smith and G. Brown, *Cochair*. Jack Pine Symp. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. COJFRC Symp. Proc. 0-P-12.

Chong, N. and Juzwik, J. 1988. Incidence, severity and silvicultural significance of stem rust diseases of jack pine in artificially regenerated areas of Northwestern Ontario. Ont. Min. Nat. Resour., Pest Control Sect., Maple, Ont. Rep. PC-34. (abbrev.)

Corbett, P. 1989. Cost efficiency of jack pine regeneration options. *in* Prov. For. Comm. field tour guide. Ont. Min. Nat. Resour., Northwestern Region, Kenora, Ont.

Drew, T.J. and Flewelling, J.W. 1979. Stand density management: an alternative approach and its application to Douglas-fir plantations. For. Sci. 25(3):528–532.

Janas, P.S. and Brand, D.G. 1988. Comparative growth and development of planted and natural stands of jack pine. For. Chron. 64(4):320–328.

LeBlanc, P.A. and Towill, W.D. 1989. Key to jack pine site productivity for North Cental Ontario. Ont. Min. Nat. Resour., Northwestern Ont. For. Tech. Devel. Unit, Thunder Bay, Ont. Rep. No. 32. 27 p.

McCarter, J.B. and Long, J.N. 1986. A lodgepole pine density management diagram. Western J. Appl. For. 1:6–11.

Peterson, W.C. and Hibbs, D.E. 1989. Adjusting stand density management guides for sites with low stocking potential. Western J. Appl. For. 4(2):62–65.

Reineke, L.M. 1933. Perfecting a stand-density index for even aged forests. J. Agric. Res. 46(7):627–638.

Riley, L.F. 1973. Operational trials of techniques to improve jack pine spacing. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Rep. 0-X-180. 26 p.

Sims, R.A., Towill, W.D., Baldwin, K.A. and Wickware, G.M. 1989. Field guide to the forest ecosystem classification for Northwestern Ontario. Ont. Min. Nat. Resour., Toronto, Ont. 191 p.

Smith, B.W. 1984. Aerial seeding requirements for jack pine regeneration. p. 78-86 *in* C.R. Smith and G. Brown, *Cochair*. Jack Pine Symp. Dep. Environ., Can For. Serv., Sault Ste. Marie, Ont. COJRC Symp. Proc. O-P-12.

Smith, C.R. 1984. Precommercial thinning in jack pine with particular reference to experiments in Northeastern Ontario. p. 122–130 *in* C.R. Smith and G. Brown, *Cochair*. Jack pine Symp., Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. COJFRC Symp. Proc. 0-P-12.

Towill, W.D., Barauskas, A. and Johnston, R. 1988. A pre-cut survey method incorporating the Northwestern Ontario forest ecosystem classification. Ont. Min. Nat. Resour., Northwestern Ont. For. Tech. Devel. Unit, Thunder Bay, Ont. Tech. Rep. No. 2.

Towill, W.D. and White, R.G. 1987. Prime site management strategy for North Central and Northwestern regions: the development of a dynamic forest management support system. Ont. Min Nat. Resour., North Central Region, Thunder Bay, Ont. and Northwestern Region, Kenora, Ont. (Internal Rep.).

Van Damme, L. and McKee, K. 1991. The extent and nature of seeded jack pine clumping following disturbance in Northwestern Ontario. Report under preparation for OMNR by KBM Forestry Consultants, Thunder Bay, Ont.

Vassov, R. and Baker, W.D. 1988. Precommercial thinning of jack pine. Ont. Min. Nat. Resour., Northwestern Ont. For. Tech. Devel. Unit, Thunder Bay, Ont., Tech. Rep. No. 12. 25 p.

Wang, E., Erdle, T. and Roussell, T. 1987. FORMAN wood supply model: user manual. New Brunswick Exec. For. Res. Comm. Inc. and N.B. Dep. Nat. Resour. and Energy, Fredericton, N.B.

Willcocks, A.J., Bell, F.W., Williams, J. and Duinker, P.N. 1990. A crop planning process for Northern Ontario forests. Ont. Min. Nat. Resour., Northwestern Ont. For. Tech. Devel. Unit, Thunder Bay, Ont. Tech. Rep. No. 30. 159 p.

# SPACING AND THINNING IN NORTH CENTRAL REGION

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## ABSTRACT

The need to thin and space plantations and natural regeneration is well recognized. Spacing projects in relatively pure coniferous stands have, however, only occasionally been carried out, usually in conjunction with special sources of funding being available. In the 5-year period between 1984 and 1989, 517 ha of regeneration have been thinned. However, one should consider the removal of aspen (*Populus* spp.) from areas that would normally become mixedwood stands basically as thinning operations. If this work is also included, then over the past 5 years, an additional 3,366 ha of manual cleaning and a portion of the aerial cleaning (by means of herbicides) program could be considered as thinning and improvement operations.

Forest modeling indicates that future wood-supply targets may be more easily met if overstocked regenerating stands are thinned in order to lower the age at which they can be harvested.

## RÉSUMÉ

On reconnaît tout à fait qu'il est essentiel d'éclaircir et de contrôler l'espacement des arbres des plantations et de permettre des régénérations naturelles. Toutefois, l'espacement des arbres dans des peuplements de conifères relativement purs n'a été effectué qu'à l'occasion, habituellement au moment où des fonds spéciaux ont été accessibles. Pendant la période de cinq ans s'échelonnant de 1984 à 1989, on a éclairci 517 ha de terres forestières régénérées. Toutefois, il faut considérer que l'élimination des peupliers (*Populus* spp.) dans les zones que deviendraient normalement des peuplements mixtes constitue essentiellement une opération d'éclaircie. En conséquence, si l'on tient compte de ce fait, au cours des cinq dernières années, le dégagement manuel d'une superficie supplémentaire de 3 366 ha et le dégagement de certaines zones au moyen de l'application aérienne d'herbicides représentent des opérations d'éclaircie et d'amélioration.

Des études de modélisation révèlent qu'à l'avenir il sera peut-être plus facile d'atteindre les objectifs en matière d'approvisionnement en bois si l'on éclaircit le matériel excessif dans les peuplements en voie de génération afin de réduire l'âge d'exploitabilité.

## CURRENT SITUATION

### Precommercial Thinning and Spacing

The North Central Region of Ontario comprises five administrative districts — Atikokan, Thunder Bay, Nipigon, Geraldton and Terrace Bay (Fig. 1).

During the period from 1984/1985 through 1988/1989, regeneration treatments were prescribed for an average of 26,050 ha per year. Planting accounted for an average of 16,304 ha, 63% of the total. An average of 9,745 ha, 37% of the total regeneration program, was treated through lower-cost techniques relying on either natural or direct seeding. Scarification and direct seeding accounted for 23% of the prescribed regeneration program (Fig. 2).

In North Central Region, tending has traditionally been regarded as an important component of the overall regeneration program. However, by far the majority of tending operations have been conducted through the aerial application of herbicides in order to protect investments made in plantation establishment.

During the 5-year period from 1984/1985 through 1988/1989, stand-improvement operations were undertaken by means of spacing on an average of 103 ha/year and manual cleaning on an average of approximately 673 ha/year. By comparison, herbicides were applied on an average of 14,113 ha/year (Fig. 3).

Figure 4 is a comparison of the area treated by means of stand-improvement operations with the area regenerated through low-cost techniques. It is evident that there is the potential for considerable expansion of the thinning and improvement program across the region. Despite this, a number of operations have been under-

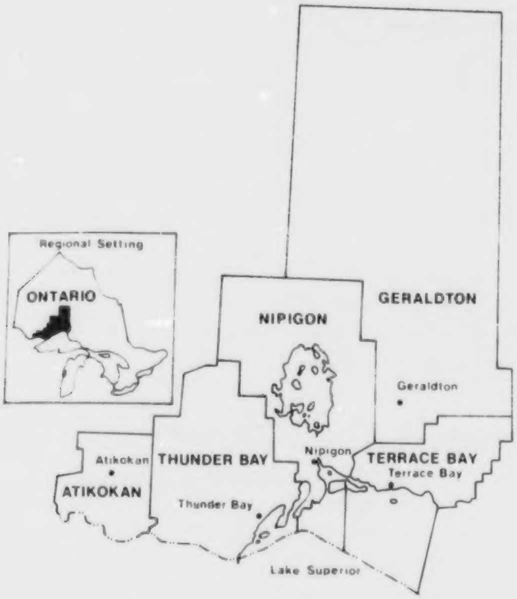
Regional Setting
ONTARIO
NIPIGON
GERALDTON
Geraldton
Atikokan
THUNDER BAY
Nipigon
TERRACE BAY
Terrace Bay
ATIKOKAN
Thunder Bay
Lake Superior

*Figure 1. Administrative districts of the North Central Region of Ontario.*

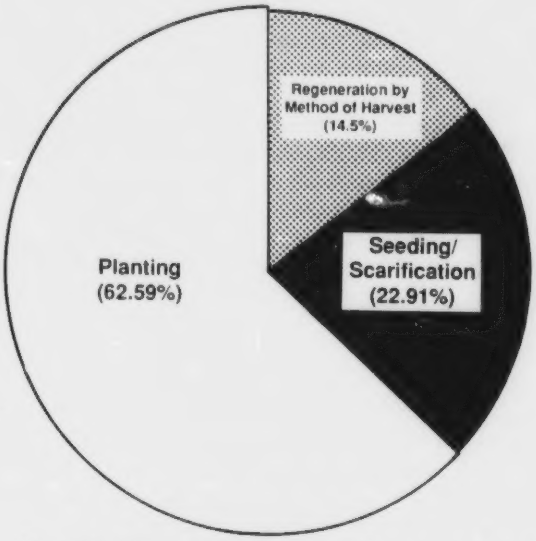

*Figure 2. Average annual regeneration program in the North Central Region of Ontario from 1984/1985 to 1989/1990.*

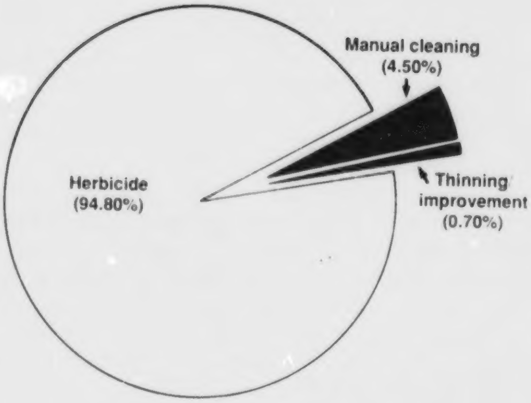

*Figure 3. Average annual stand-tending operations from 1984/1985 to 1989/1990 in the North Central Region of Ontario.*

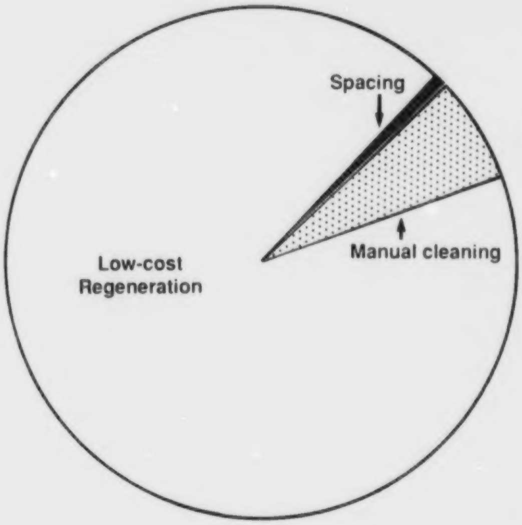

*Figure 4. Comparison of the areas treated by means of stand-improvement operations and low-cost techniques in the North Central Region of Ontario from 1984/1985 to 1989/1990.*

taken and some expertise has been developed in the region with respect to spacing and thinning.

Treatment was first conducted in Atikokan District in 1985/1986. To assess the effectiveness of the treatment, control and treatment plots were established and baseline data were collected. Pre-treatment stand densities were determined for the control and treated areas and stem analysis was done with a TRIM (Tree Ring Increment Measurement) unit. The sampled pre-treatment densities ranged from 16,300 to 31,700 stems/ha. The post-treatment densities averaged 3100 stems/ha. Remeasurement will be done in the future to evaluate treatment response.

The stands in which treatment has been undertaken were established by direct seeding. Observations of overstocked natural stands indicate that direct-seeding treatments may warrant consideration as the prescription for natural jack pine (*Pinus banksiana* Lamb.) regeneration after scarification, provided that cones are left in the cutover after harvest.

The stands in which precommercial thinning is likely to be a valuable silvicultural tool are sites on which jack pine regeneration can be established through low-cost techniques. It is unlikely that there will be an increase in the overall yield of spaced jack pine stands compared with unspaced stands. The advantage in the treatment lies in the fact that the stands are likely to become operable 20 to 30 years sooner in terms of conventional log-size standards.

Enough experience has been gained that the stand-improvement prescription currently used really covers both cleaning and thinning in one operation. In this way, portions of stands that require thinning are treated at the same time that other portions of the stand are manually cleaned. In addition, all species are now being thinned in the same operation. If poplar (*Populus* spp.) is dominant in a portion of the stands and desirable conifers are scarce or severely suppressed, the poplar will be spaced.

### Commercial Thinning

Norkooli and Towill (1986) indicated that there are approximately 20,000 ha of plantations in North Central Region that could be commercially thinned or at least treated through stand-improvement operations. Further, within 5 years, it is estimated that another 50,000 ha could be ready for thinning or improvement.

In the past few years, commercial thinning has been done on a trial basis in plantations in Thunder Bay District and in fire-origin jack pine stands in Geraldton District.

Based on their work in Thunder Bay District in 1986, Bax and Van Damme (1987) estimated felling costs for commercial thinning at between $300 and $500 per hectare — similar to the costs for precommercial thinning. Unfortunately, the cost of bringing the timber to roadside so that it can be utilized is unlikely to be recovered at current roundwood prices. The total cost of felling, processing and forwarding the timber to roadside in the Thunder Bay operation was approximately $2900/ha. After deducting timber revenues, the net cost of the thinning was approximately $1300/ha.

It is difficult to predict whether or not there will be an application for commercial thinning in situations where the timber is being grown primarily for pulp. For stems to reach commercially operable size by conventional standards, stands are thinned approximately 10 years after the time at which they would have benefited most from a silvicultural standpoint[1]. Consequently, such stands may be clearcut.

Where solid wood is the objective, it is likely that commercial thinning will have some application, especially considering the number of plantations that have been established at a 2-m spacing.

## WHAT DOES THE FUTURE HOLD?

Most of the spacing and thinning work undertaken to date has resulted from a stand-level decision. That is, field staff have identified particular stands suitable for treatment. From the promising results that these treatments have yielded and the fact that the use of forest modeling and crop planning is expanding, it can be expected that low-cost regeneration followed by precommercial thinning will become a widely accepted forest-level strategy.

Table 1 contains average unit costs for various regeneration methods. This does not imply that any treatment can be used on any site nor does it imply that treatment costs are necessarily the same on all sites. However, once the cost of producing planting stock is considered, it becomes evident that alternative approaches to satisfying future mill demands are perhaps warranted. This is especially true if hardwood regeneration can satisfy some of the future mill requirements.

Figure 5 provides an indication of the age-class distribution for the jack pine forest units in North Central Region. Figure 6 illustrates the age-class distribution for the spruce forest unit. When these are combined, the result is Figure 7. Age-class distributions for particular management units may vary — the imbalance in age classes may be more or less serious.

Depending on the extent of the imbalance in age classes, simply regenerating more current cutovers may not provide sufficient operable timber to support an even flow of wood. Experience with crop planning models such as FORMAN indicates that a combination of planting and spacing of low-cost regeneration may be required in order to sustain an even flow of timber.

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[1] Van Damme, L. 1987. Summary of two seasons experience with manual thinning systems in northwestern Ontario. K.B.M. Forestry Consultants Inc., Thunder Bay, Ont. Unpubl. Rep.

Table 1. Average (1989) unit cost for silvicultural operations in the North Central Region of Ontario.

| | Cost ($/ha) | | | | | |
|---|---|---|---|---|---|---|
| | Stock production | Site preparation/ scarification | Planting/ seeding | Two aerial cleanings[b] | Spacing | Total cost |
| Natural regeneration | | | | | | |
| Hardwood | 0 | 0 | 0 | 0 | 0 | free |
| Conifer | 0 | 284 | 0 | 242 | 537 | free-1063 |
| Direct seeding | 0[a] | 284[a] | 37[a] | 242 | 537 | 321-1100 |
| Planting | | | | | | |
| Containers | 355[a] | 284[a] | 354[a] | 242 | – | 993-1235 |
| Bareroot | 410[a] | 284[a] | 509[a] | 242 | – | 1203-1445 |

[a] basic costs (all other costs might be incurred); no attempt has been made to discount the costs
[b] by means of herbicide applications

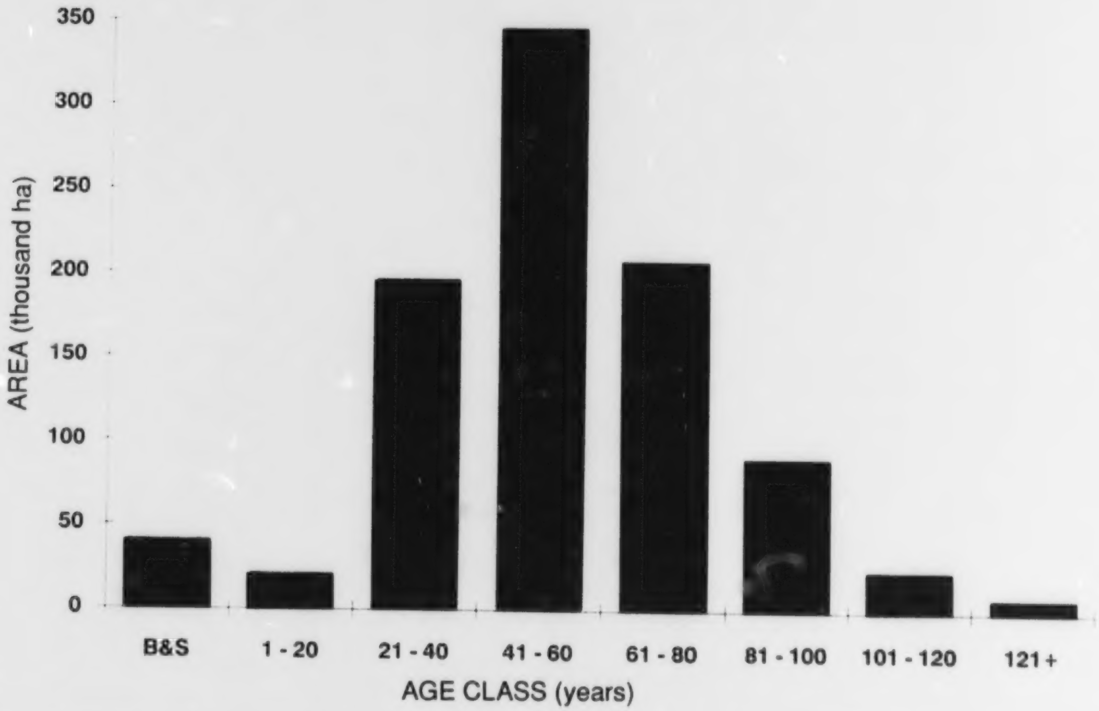

*Figure 5. Age-class distribution for the jack pine working group in the North Central Region of Ontario.*

To maintain a steady flow of wood and offset potential timber shortages, a number of options are available. These include:

- ensuring that the cutting regimes adopted minimize the volume of timber lost through natural mortality;
- providing access to those areas in which the required harvesting is to be carried out; and
- reducing the age at which existing young growth becomes operable so that a more even flow of timber is available. Precommercial thinning presents the fewest logistical problems in this regard but commercial thinning is also an option.

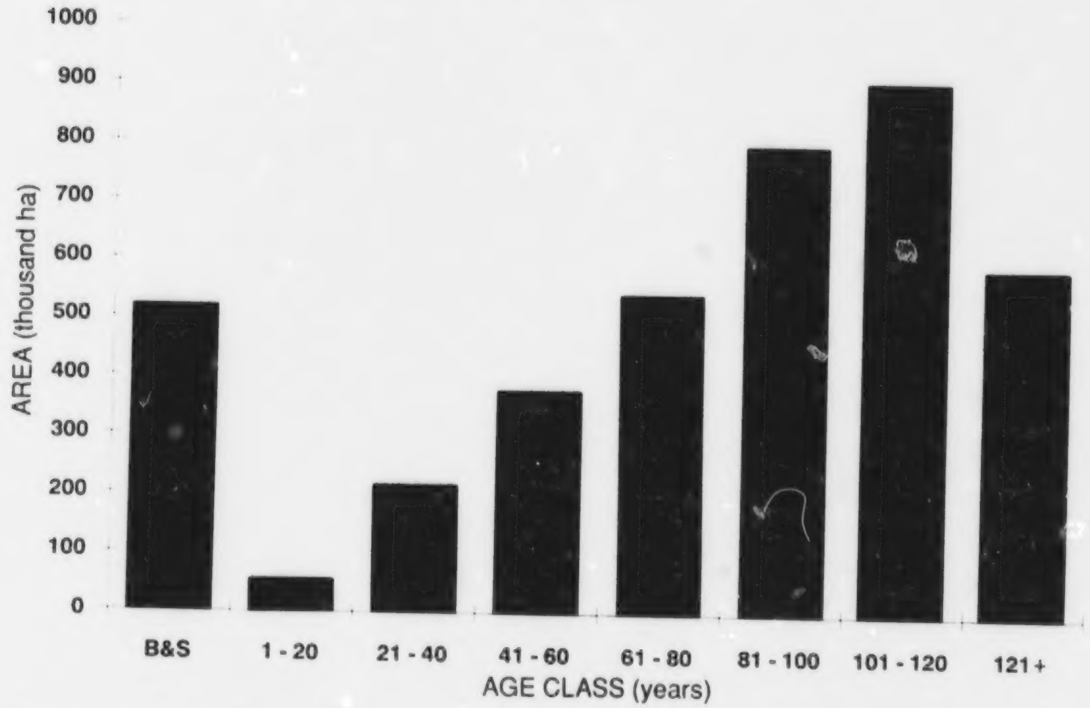

*Figure 6. Age-class distribution for the spruce working group in the North Central Region of Ontario.*

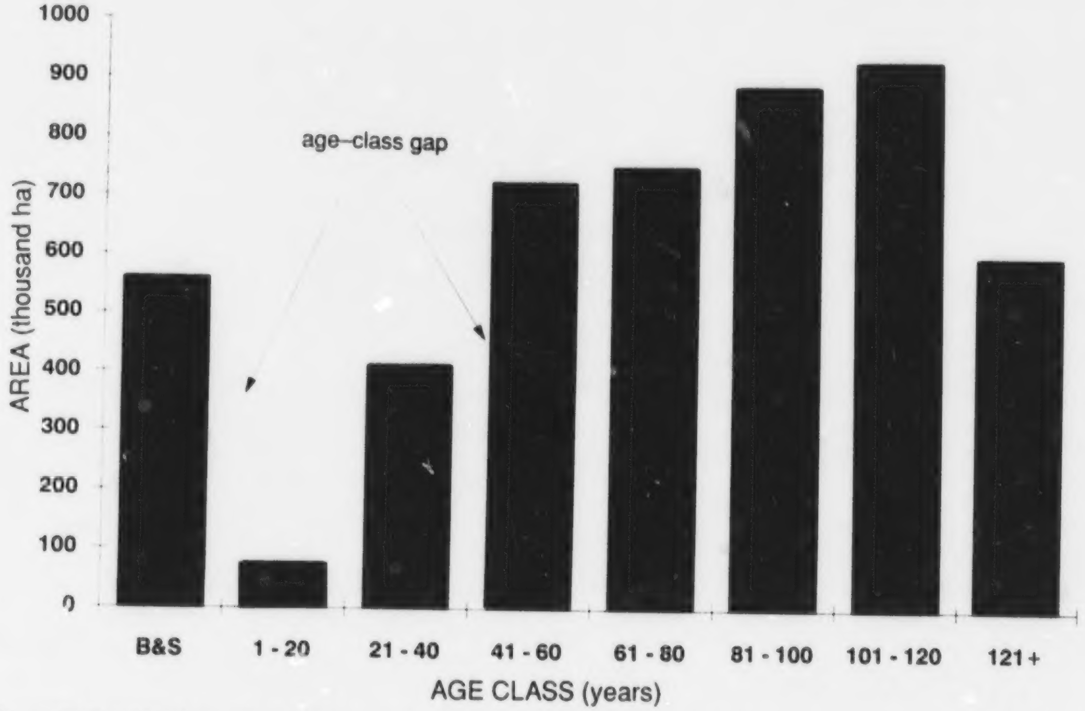

*Figure 7. Combined age-class distribution for the spruce and jack pine working groups in the North Central Region of Ontario.*

In the absence of the above, technological changes will be required in harvesting timber and the manufacture of wood products. For example, recycling initiatives may help reduce roundwood requirements and thus offset the potential impact of timber shortages.

Traditionally, allowable-depletion calculations have been carried out under the assumption that all timber is equally accessible and available for harvest. With the development of competing demands for resource use, it is unlikely that the entire land base will be available for timber production for much longer. Foresters who are already dealing with tight timber supplies recognize that one of the key considerations in resolving resource-use conflicts is having flexibility in the allocation of stands for harvest. Future conflicts may be reduced by increasing the area eligible for harvest by accelerating the operability of younger stands.

One of the remarks that we, as foresters, make today is that we wish we had done more to artificially regenerate our forest 30 to 40 years ago. Hindsight is always 20-20. It would be an unfortunate situation if, in 20 to 30 years from now, we regret not having thinned stands when we had the opportunity. The application of crop planning and forest modeling principles will be a valuable component in timber management decision-making.

## LITERATURE CITED

Bax, H.A. and Van Damme, L. 1987. Implications for profitable thinning: utilization of a mini-forwarder and small skidder. p. 75–84 *in* R.L. Galloway, R.M. Greet, D.W.J. McGowan and J.D. Walker. Primeval improvement: the new forestry age. Gov't of Can., Can. For. Serv., Sault Ste. Marie, Ont. COJRC Symp. Proc. O-P-15. 134 p.

Norkooli, R.J. and Towill, W.D. 1986. Provincial forest technical meeting field tour. Ont. Min. Nat. Resour., North Central Region, Thunder Bay, Ont. 42 p.

# SPACING IN THE NORTHERN REGION OF ONTARIO

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## ABSTRACT

In selecting silvicultural prescriptions, we must consider both the forest structure and the requirement for sustainable development in the specific forest to be managed. Simply planting more trees does not make us better managers. An example of crop planning in the Northern Region of Ontario illustrates the opportunity for using spacing prescriptions to maximize the reduction in rotation length in the existing forest in an attempt to address age-class imbalances.

## RÉSUMÉ

En matière de sélection des prescriptions sylvicoles, nous devons considérer à la fois la structure de la forêt et la condition nécessaire d'un développement durable dans une forêt donnée devant faire l'objet d'un aménagement. Le fait de planter simplement un plus grand nombre d'arbres ne fait pas de nous de meilleurs aménagistes. Un exemple de planification de peuplements forestiers dans la région du nord de l'Ontario illustre la possibilité d'utiliser des prescriptions d'espacement pour maximiser la réduction de la période de rotation de la forêt existante en vue de traiter les inégalités des classes d'âge.

## SPACING IN NORTHERN REGION

Having worked in different parts of Canada, I have had the opportunity to look at forest management in both British Columbia and New Brunswick. People may criticize Ontario for lacking vision in terms of spacing opportunities and for lacking a good resource inventory, but I have found from experience that the work that we do in Ontario is done very well. Take a look at our silviculture program: Northern Region has a proud tradition of good forestry practices.

We have learned how to grow seedlings and grow them well. We have learned how to plant those seedlings and we have made great strides in addressing the regeneration gap. We are currently looking at the trees we have now and the trees we will have in the future. We are turning our focus to new endeavors, particularly spacing. In this paper, I will address the topic of spacing opportunities in the Northern Region of Ontario.

In Northern Region, we do not have the same ground conditions that Mike Waldram spoke about in the context of northwestern Ontario. We do not have major fire losses, nor do we have extensive areas of naturally regenerated jack pine (*Pinus banksiana* Lamb.). We have extensive areas of peatland dominated by black spruce (*Picea mariana* [Mill.] B.S.P.), much of which does not regenerate adequately by natural means. We must, therefore, plant, and as such there will always be a considerable planting program. Our forest management supervisors have recently taken major strides to put more attention on other silvicultural practices such as low-cost regeneration, increased opportunities for prescribed burning, increased use of shelter cones for seeding, and more tending and thinning activities. We look at these as our management tools, and we must increase our active use of them.

We have recently negotiated with E.B. Eddy Forest Products Ltd. to provide both more spacing opportunities and the required financing. Where such opportunities occur, we intend to proceed with them diligently. Many things must be taken into consideration to obtain effective results. We must not simply get on the bandwagon and space a whole bunch of timber, whether or not spacing is needed. We do not plant all areas, nor do we tend all areas.

What are my management objectives and what are the tools and techniques available for me to use? Considerable effort is being expended in wood-supply modeling. The FORMAN model is being used in New Brunswick and we are attempting to tie in geographical information systems (GIS) technology and optimization routines in an adaptation called NORMAN. Currently, we are trying to decide what our management objectives are and what silvicultural strategies we must address to secure our long-term wood supply. Depending on the age-class distribution of the stands, there could be different management scenarios for different management units. We have to look at each management unit individually and determine when the age-class distribution will be in balance. We must also ascertain the silvicultural opportunities that are available. Subsequently, management prescriptions must be prepared for each unit to include all possible products, including veneer, saw timber and fiber. One size does not fit all.

We have predetermined ideas of what we want the forest to look like. It is easy to have a mental image of what is needed and wanted, but it is another thing to attain this goal. When we approach biologists, wildlife habitat personnel, etc., they get very envious and tell us what a great opportunity we have in the forest. They say to us, "The trees do not move", "you can go hug them when you need to", "you can measure them". We can forecast what kind of trees we have and, in theory, there is a very simple approach to managing them.

When we get into the details, it is no longer that simple. Some of our forest types experience more competition than others. We are not sure of the species composition. We have to look at various wood-supply models or opportunities to help evaluate the potential of various management scenarios. For example, when we first started in New Brunswick we had six yield curves that represented all species, age classes and site types in the whole province — a simplistic overview. Five years later, when the next management plan was done, there were 268 yield curves. We learned that trees grow differently on different sites and under different management regimes. We are now approaching that same philosophy in Ontario; the philosophy is simple in principle, but gets more detailed in reality.

We have management options, and this creates many questions. With a naturally regenerated stand, a forester can ask when to thin or space it. Should one do commercial thinning? What happens if one does nothing? When we discuss long-term wood supply, whether we like to admit it or not, we are making predictions about that wood supply. Hypothetically, when a stand is planted, we are predicting that we can return to harvest the stand in 70 years. We are also predicting that the volume will be 170 $m^3$/ha. However, if the stand is not spaced properly or if competition is not controlled, the yield will not be what is predicted and a wood-supply problem will result.

One of our goals is to ascertain the most appropriate technique to help evaluate our management prescriptions in terms of how the initial forest is growing: should we have a particular management intervention, and what effect will it have? The response to such interventions will vary according to the site and the condition of the forest. Management interventions could occur in the form of a planting program or a tending of plantations (e.g., brush cleaning or precommercial spacing). All such interventions would be incorporated into the forest-growth models. In Northern Region, we are looking at increasing some of these interventions, specifically spacing, but with no differentiation made between spacing and cleaning. For clarification, "spacing" is done in natural stands and seeded areas, and trees are spaced so that proper stocking and density controls are maintained. "Cleaning" is done in plantations to ensure that if 175 $m^3$/ha is expected in 15 years, with 2000 stems, then we will ensure that there are 2,000 and not 10,000 stems. A commercially viable product is the desired end result.

It is relatively easy to visualize what those plantations or spaced areas would look like, but it becomes much more difficult when one is on the ground trying to decide whether the spacing should be 2.4 or 2.7 m and what the end result will be. How should the operation be done to achieve the proper spacing? Spacing gives us some opportunities to create a forest with the type of structure and the species we want. Taking out the diseased and deformed trees must be part of our spacing programs if we want to improve quality.

In addressing the current wood-supply issue, several questions need to be asked. When should we plant? When should the plantation be thinned? What effect will this have on growth? We realize that because of the natural age-class structure of our forest, we lack wood in the 21- to 60-year-old category. If plantations will not become mature and operable until 50, 60 or 70 years and there will be a wood-supply deficit in 30 or 40 years, then plantation establishment will not help. It will make more sense to direct funds into a spacing program that utilizes naturally regenerated areas. The return on investment will be faster and a supply of wood will be available for harvesting during the currently predicted period of shortage.

Spacing is a very viable option where the over-dense natural stands are available. If there are no naturally regenerated or seeded areas, then spacing obviously cannot be done. In Northern Region, we are assessing where opportunities might be available to us now. The key is to realize what we have now, predict what we want in the future, understand the various management scenarios available and implement the interventions that will be necessary. One of the concerns I have is with plantations. We plant cutovers, and by year 5 or year 7 we call them "free to grow". Subsequently we say, "I will see you in the year 2042." Will that stand have the right diameter and stem distribution? We *must* go back and clean those plantations.

## Advantages to Spacing

The biggest advantage of spacing in northern Ontario is the 10-year reduction in rotation length that generally occurs. If a stand is already 10 to 20 years old and is spaced, it should be possible to harvest that stand 10 or 20 years earlier, and there is an opportunity to choose the species and the trees that will be part of the final crop. We can undoubtedly get better growth response through the use of spacing. Hence, we can exercise density control and ensure that volume is being added to the desired stems by conducting spacing. The key aspect in terms of the New Brunswick wood-supply situation is to know when the plantation should be harvested. A plantation is ready for harvest when the piece size is 0.152 $m^3$ or 0.12 $m^3$ per tree, depending on the part of the province. The number of stems per unit area will have a significant effect on how long it will take to produce that volume on an individual tree. If there is much competition, it will take longer, perhaps 60 rather than 40 years, to reach the desired volume per tree. Can we afford to wait?

Some preliminary work on wood-supply modeling has been done in Northern Region. We are assessing the opportunities that manifest themselves if no silviculture is done, if planting is done, if spacing is done, and so on. We examined opportunities in one management area and found that, because of the age-class balance, putting more money into planting would not give any significant return for somewhere between 60 and 70 years. However, if we put more money into spacing in the same forest, the opportunity exists to increase the harvest by hastening the availability of spaced stands for harvest. This will only be achievable if there are well established naturally regenerated or seeded areas to space.

## WHAT WE NEED

To do proper forest management, we must know what we have and what potential our sites have. We need an improved inventory. We must know which stands have regenerated adequately by natural means, which stands must be spaced, and which plantations must be cleaned. We must be able to tie our activities and results into the Forest Resource Inventory and be able to "track" our progress. We must obtain better growth and yield information to help predict the expected result and evaluate our management scenarios. We are embarking on these approaches with the cooperation of the forest industry and the research community through a growth and yield program for all of Ontario.

In closing, I would also like to mention the concept of sustainable development. If we want to sustain our forest industry and the communities that depend on it, there are forest management techniques that will help us. We must turn the concept of sustainable development into a commitment to action. This commitment will create more work in spacing and basic silviculture. We look at spacing as being an integral part of our silviculture program. Future forest management should take into account the yields that are needed, the expectations over time, and how the forest can be managed to create these conditions and meet these needs.

# SPACING AND THINNING IN THE NORTHEASTERN REGION OF ONTARIO

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## ABSTRACT

Thinning and spacing are critical components of crop planning, and provide opportunities to increase tree growth rates, enhance product quality and reduce rotation ages. Thinning projects carried out in the Northeastern Region of Ontario over the past 5 years are described in terms of species treated, stand age, site conditions, treatment cost, and, where possible, growth response.

There is a great demand for sawlogs in this region. Both precommercial and commercial thinning, as part of a crop-planning strategy, can provide opportunities for increasing the supply of sawlogs from the natural forest and from plantations. However, markets for the low-quality products of such small thinnings are required if we are to take advantage of these treatment opportunities.

Future initiatives will provide improved growth rates in natural stands, larger areas thinned as plantations age, and the use of products derived from thinnings. Field monitoring and analysis of growth and yield will also be required to measure the effects of treatment.

## RÉSUMÉ

L'éclaircie et l'espacement sont deux aspects essentiels de l'aménagement d'un peuplement. En effet, ces techniques permettent d'améliorer le taux de croissance des arbres, d'obtenir un produit de meilleure qualité et de réduire l'âge d'exploitabilité. Suit une description des projets d'éclaircie poursuivis dans le nord-est de l'Ontario au cours des cinq dernières années en fonction des espèces touchées, de l'âge des peuplements, des conditions locales, du coût du traitement et, le cas échéant, de la variation du taux de croissance.

La région connaît une forte demande de grumes de sciage. Dans le cadre de la stratégie d'aménagement, l'éclaircie précommerciale et commerciale peut accroître le nombre de grumes venant des forêts naturelles et des plantations. Toutefois, on a besoin de débouchés pour les produits de qualité secondaire issus des petites éclaircies si l'on veut exploiter tout le potentiel d'un tel traitement.

Les projets entrepris dan l'avenir contribueront à accroître le taux de croissance des peuplements naturels, à éclaircir de plus grand secteurs à mesure que vieillit la plantation et à utiliser les produits de l'éclaircie.

## INTRODUCTION

In these difficult times of dwindling resources, budget constraints and growing public concern for the environment, we can all understand the increasing difficulty of meeting Ontario's demand for wood products. Considerable attention must be paid to proper planning and effective spending if forest managers are to continue to supply public demands while maintaining healthy forests for future generations.

In the Ontario Ministry of Natural Resources' (OMNR) Northeastern Region, we have developed certain models to assist us in practicing good forest management. PriSMa, an acronym for Prime Site Management, was a model initiated in the mid 1970s by the Regional Forester to assist in the revision of the then Forest Production Policy target. The Northeastern Region has also developed SIAM, the Silvicultural Investment Analysis Model, in order to rationalize silvicultural prescriptions economically. Essentially, SIAM is a computerized cost/benefit analysis model that can assist forest managers in choosing the most cost-effective management prescription for a given operational group.

Use of this program in Blind River District has shown that thinning red pine (*Pinus resinosa* Ait.) plantations causes substantial increases in product values at rotation age and is, therefore, one of the most efficient uses of funding. It is estimated that these plantations will be worth $20,000/ha, not including the value of previous thinnings, as a result of pole, veneer and cabin log production (B. Fox, OMNR, Blind River, personal communication).

## ACCOMPLISHMENTS TO DATE

Over the past 5 years, several thinning or spacing projects have been conducted in Northeastern Region. Because of the abundance of the hardwood and, in some districts, the white pine (*Pinus strobus* L.) working groups, considerable work has been done as "improvement cuts". Since these are not true "thinnings", they will not be discussed in detail in this paper.

Some thinning trials have also been conducted in yellow birch (*Betula alleghaniensis* Britton) regeneration. These trials were established in the Blind River and Sault Ste. Marie districts. Crop trees were thinned to 10, 20, 30 and 40% of the stand height, with all stems removed within the specified distances from the crop trees. Results to date show that thinning to spacings of somewhere between 30 and 40% of crop tree height produced the best results. In addition, it was evident that only those trees in direct competition with the crop trees should be removed, and that crowns of crop trees should be clear of competition for a distance of 2 m from the edge of the crown. Studies will be continuing in this area.

Table 1 provides a summary of the area thinned in Northeastern Region from 1985 to 1989. It is apparent that most of the thinning work in the region has been conducted in red pine and jack pine (*Pinus banksiana* Lamb.) stands. Some work has been done in natural stands, but the majority has occurred in plantations.

Table 1. Area thinned, by species and year.

| | Area thinned (ha) | | | | | |
|---|---|---|---|---|---|---|
| Species | 1985 | 1986 | 1987 | 1988 | 1989 | Total |
| Red pine | 58 | 73 | 74 | 100 | 53 | 358 |
| Jack pine | 314 | 167 | – | 8 | 13 | 502 |
| White pine[a] | 14 | 59 | 107 | – | 15 | 195 |
| White spruce[b] | – | 5 | – | – | – | 5 |
| Hemlock[a,c] | – | 237 | 110 | 335 | – | 682 |
| Yellow birch | – | 10 | 99 | – | – | 109 |
| Total | 386 | 551 | 390 | 443 | 81 | 1851 |

[a] "improvement" cuts

[b] *Picea glauca* (Moench) Voss

[c] *Tsuga canadensis* (L.) Carr.

As would be expected, red pine plantations were established on deep, dry to fresh sites with fine to coarse sandy soils. The stands were usually highly stocked, anywhere from 80 to 100%. The first thinnings occurred when the stands were anywhere from 18 to 55 years old, with most treatments being applied at 20 to 30 years. A variety of prescriptions were implemented, including the following:

- selective removal of small, poor-quality stems with little regard for the amount removed;
- selective thinning from below to remove one-third of the stems;
- alternate-row thinning;
- removing every third row;
- removing every fourth row, alone or in combination with selective removal of poor-quality stems in remaining rows;
- 3- to 4-m spacing;
- 1.8-m spacing; and
- reducing the basal area to one-half the present value.

The pros and cons of these various thinning schemes are discussed in the next section.

Except for operations in the Kirkwood Forest, 70% of the operations were precommercial thinnings. The precommercial thinnings were accomplished through "make work" programs, by Junior Rangers, by OMNR staff, and, occasionally, by contractors. Costs of thinning ranged from $100/ha for simple, mechanical row thinning to $1600/ha where marking was involved and brush and chainsaws were used. Most of the operations cost approximately $500/ha.

## THE KIRKWOOD FOREST

The Kirkwood Forest, named "Forest of the Year" for 1990, is located just north of the town of Thessalon, and contains extensive areas of pine (*Pinus* spp.) plantations. The outwash plains on which the stands grow are mainly site class I, with some site-class II stands, and provide optimum growing conditions for pines. Most of the plantations, which cover 4400 ha, were established in 1928; 2500 ha are red pine stands (K. Hoback, OMNR, Blind River District, personal communication).

Thinning began in the Kirkwood Forest in 1949 with the establishment of the Beckwith red pine permanent sample plots. Half-acre (0.2 ha) plots were established using various residual basal areas as the thinning prescription. A control plot was also maintained to show the effects of not thinning the trees originally planted at 6-foot (1.8 m) spacing. Table 2 gives a summary of the results of this experiment to date.

Table 2. Data for the Beckwith red pine permanent sample plots, Kirkwood crown management unit.

| | Plot | | | |
|---|---|---|---|---|
| | 6 | 7 | 8 | 9 (Control) |
| residual BA ($m^2$/ha) | 22 | 26 | 29 | n/a |
| total volume from thinnings ($m^3$/ha) | 227.4 | 238.6 | 225.3 | 61.6 (mortality) |
| standing volume at age 59 ($m^3$/ha) | 402.3 | 439.4 | 455.5 | 676.6 |
| total volume produced ($m^3$/ha) | 629.7 | 678.0 | 680.8 | 738.2 |
| present density (stems/ha) | 96 | 117 | 143 | 321 |
| average DBH (cm) | 28.7 | 27.2 | 25.1 | 20.6 |
| average height (m) | 24.8 | 24.7 | 24.5 | 24.6 |
| live crown (%) | 32 | 32 | 29 | 22 |

Each plot was thinned four times (in 1949, 1955, 1972 and 1983). The plots identified as plots 6, 7 and 8 were thinned to 22, 26 and 29 $m^2$/ha of basal area, respectively. Plot 9, a control plot, was not thinned. It is important to note that each plot produced similar amounts of total volume, with differences arising in the amount of merchantable material harvested. No volume was removed from the control plot, and the present stand would only produce pulpwood. Plot 6, on the other hand, produced a total of 629.7 $m^3$/ha, of which 75% would be merchantable, a percentage considerably greater than that thought to be merchantable in an unthinned stand (B. Fox, OMNR, Blind River District, personal communication).

Another key point to note is the increase in DBH on the thinned plots versus the unthinned plots. Plot 9 had an average DBH of 20.6 cm, whereas plot 6 had an average DBH of 28.7 cm. In terms of sawlog volume produced, this is a considerable increase.

The proportion of live crown also differed substantially between thinned and unthinned plots. Plot 6 had a live-crown ratio (height of live crown divided by total tree height) of 32%, whereas the live-crown ratio in plot 9 was only 22%. It has been reported that optimum growth and proper branch pruning for most conifers is maintained with a live-crown ratio of 33% (B. Fox, OMNR, Blind River District, personal communication).

Results from these experimental plots demonstrate the considerable benefits of thinning and the losses that are incurred when thinning does not take place. In terms of the optimum thinning regime, the results suggest that a thinning even heavier than that used in plot 6 would result in still higher merchantable-volume production, larger products and would still maintain the desired 33% live-crown ratio (B. Fox, OMNR, Blind River District, personal communication).

Over the years, it was found at Kirkwood that thinning to a particular residual basal area did not always achieve the desired results, perhaps because crowns of crop trees were not properly released and crown deformity occurred. For this reason, a new prescription was introduced. The present thinning regime is, first, to remove every third row as well as selectively removing poor-quality trees in the remaining rows, so that no more than 33 to 50% of the stems have been removed. When rows cannot be determined, forced rows 3.7 m wide and 9 m apart are created to open up the stand. The purpose of the first thinning is to provide access to the stand during future thinnings and to space the crop somewhat. This thinning is usually carried out when the stand has an average DBH of 16 cm or is 25 to 30 years old. Precommercial thinnings are not usually considered because of their expense.

A second thinning occurs 5 to 7 years later with the purpose of increasing overall stand quality and spacing. Trees are spaced at 2.5 to 3 m. Eight to 10 years later, when tree height growth has reduced the spacing to less than 19% of the stand height, crop trees are selected and surrounding trees are removed to space the trees at 22% of the stand height. Subsequent thinnings of this nature will occur when the stand height changes significantly enough to warrant increased spacing of the crop trees. This 22% height-spacing rule was suggested by work done by Day and Rudolph (1971) in the Lake States and, after much consideration and deliberation, was selected for use in the Kirkwood Forest. Crop-tree selection and pruning to a height of 5.2 m, leaving 50% live crown, should be performed immediately after the first thinning (K. Hoback, OMNR, Blind River District, personal communication).

After switching to this thinning method to replace marking based on basal area, it was found that marking costs decreased. The operation is also far less subjective, since it is easier to pick the best crop trees and space them accordingly than to determine the group of trees to be left to maintain the stated basal area. The result is that crop trees are all properly spaced and crown deformity does not occur. Marking costs in the Kirkwood Forest range from \$50/ha to \$80/ha, depending on the ease of determining rows within the plantations (K. Hoback, OMNR, Blind River District, personal communication).

Occasionally, the 22% height rule is modified to take other factors into consideration. For example, a stand in an area with high snowfall that was being thinned a little later than was optimal was thinned to only 20% of stand height. This was done to protect the trees from sustaining excessive snow damage as a result of increased wind within the stand (K. Hoback, OMNR, Blind River District, personal communication). All red pine thinnings at the Kirkwood Forest are of a commercial nature. Presently, thinned trees are taken to E.B. Eddy Forest Products Ltd. in Espanola for pulping at a rate of 4000 to 5000 $m^3$ annually. Future markets with the Ministry of Transportation, for guard rails, and with the local decking industry are also being investigated. Almost no thinning is carried out in the Scots pine (*Pinus sylvestris* L.) plantations because there is presently no market for the product. From 900 to 1500 $m^3$/yr of white pine thinnings can be sold, but there is not high demand for this product either.

Yields from the Kirkwood Forest for first, second and third thinnings are estimated at 60, 45 and 68 $m^3$/ha, respectively. It is estimated that first thinnings will produce only pulpwood, second thinnings will produce an average of 80% pulp and 20% sawlogs, and third thinnings will produce an average of 60% pulp and 40% sawlogs (K. Hoback, OMNR, Blind River District, personal communication). The work at the Kirkwood Forest has thus provided Northeastern Region and the province with valuable information on red pine growth and the effects of various cultural practices.

## FUTURE WORK

From an operational perspective, Table 3 shows the anticipated thinning and spacing projects in the districts of Northeastern Region over the next 5 years. There is the potential to thin a total of 6,391 ha, a substantial increase from the 800 ha thinned during the last 5 years. In addition to these 5-year values, the three Forest Management Agreement areas in Northeastern Region have a potential area of jack pine in excess of 25,000 ha that can be thinned. If all thinnings are carried out and produce an average of 60 $m^3$/ha of pulpwood, the total wood volume produced would be 383,490 $m^3$. The market price of thinnings at E.B. Eddy in Espanola is presently between \$31/$m^3$ and \$35/$m^3$ (G. Fuller, E.B. Eddy Forest Products Ltd., Espanola, Ont., personal communication).

Table 3. Potential for thinning over the next 5 years in Northeastern Region.

| District | Area (ha) to be thinned, by species | | | | |
|---|---|---|---|---|---|
| | Red pine | Jack pine | White pine | White spruce | Total |
| Temagami | 1332 | 955 | 954 | 585 | 3826 |
| North Bay | – | – | – | – | no record |
| Sudbury | 85 | 30 | – | – | 115 |
| Espanola | 250 | – | – | – | 250 |
| Blind River | 1250 | – | – | – | 1250 |
| Sault Ste. Marie | 150 | 400 | – | – | 550 |
| Wawa | – | 400 | – | – | 400 |
| Total | 3067 | 1785 | 954 | 585 | 6391 |

There are presently two major thinning and spacing research projects under way at the Central Ontario Forest Technology Development Unit (COFTDU) in North Bay. The first is a project to create gross merchantable volume tables for red pine plantations. Thinnings from the Kirkwood forest in 1972, 1979 and 1982 were measured in terms of gross total and gross merchantable volume. The gross merchantable volumes collected will be compared with those derived by Honer (1967). Honer's standard total volume tables were developed in the late 1960s to provide a means of determining total individual-tree volumes when the diameter and height of the tree are known. Separate equations were developed for each of several of the commercial tree species in central and eastern Canada. From this comparison it will be decided whether or not Honer's equations are satisfactory for predicting individual-tree, standard gross merchantable volumes. If not, more field sampling will be required to obtain actual values for gross merchantable volume (F. Pinto, COFTDU, North Bay, personal communication).

The second project is a jack pine thinning trial being carried out in cooperation with E.B. Eddy and the University of Toronto. The objectives are to determine tree and stand development patterns, foliage and wood increment, branch size, wood quality and spacing relationships. The trial was established in a 26-year-old, overstocked stand in 1951 and was one of the first jack pine thinning trials in Ontario. Spacing after thinning varied from 1.7 to 3.4 m. The trial will be measured both destructively and nondestructively over the next 2 years. Stem-analysis techniques will be used to determine past crown sizes and relate them to tree growth. The result will be a biologically based growth and yield model.

## OPPORTUNITIES

It is apparent that the forests of Northeastern Region have the potential to produce high-quality products and that much work has occurred to determine the most efficient ways of enhancing this productivity. Final products from the Kirkwood Forest will be highly sought after by sawlog, pole and veneer mills. The region contains extensive areas of natural and seeded jack pine as well as planted red pine, jack pine and white pine, all of which will require thinning in the coming years.

One challenge facing Northeastern Region is how to achieve the necessary, primarily precommercial, thinnings when the products are not in high demand. Presently, districts within close proximity to the E.B. Eddy Espanola mill have a small market for the red pine thinnings. It is not known at this time whether there will be the possibility of an expansion of this market in the near future.

Unfortunately, as is likely the case in all regions, our silvicultural treatments are governed to a large extent by the economics of the operations and by available funding. This is also true of our hardwood management in this region. Our forests have the potential to produce high-quality products, but the markets are not available at the present time to encourage removal of the lower-quality products that would facilitate regeneration and maximize growth potential of the remaining high-value stems.

We must continue to improve our harvesting systems and thinning regimes to reduce the costs of precommercial operations and enhance the value of the final products. We have had some success by using the services of the Junior Ranger program and various "make work" projects, and are examining the efficiencies of sophisticated harvesting, processing and forwarding equipment. These efforts will continue in the future. We are also refining our knowledge of growth, yield, and tree physiology through research projects coordinated by the COFTDU.

## LITERATURE CITED

Day, M.W. and Rudolph, V.J. 1971. Thinning red pine by percent of height. Mich. Agric. Exp. Stn., Rep. No. 125. 8 p.

Honer, T.G. 1967. Standard volume tables. Forestry Branch, For. Res. and Serv. Inst., Ottawa, Ont. Inf. Rep. FMR-X-5.

# A NORTHERN ONTARIO COMPANY'S PERSPECTIVE ON THINNING AND SPACING

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## ABSTRACT

Controlling initial spacing and thinning are the two most important elements of a management program designed to produce quality sawlogs in artificial and natural forest stands. Outplanting of black spruce (*Picea mariana* [Mill.] B.S.P.) and jack pine (*Pinus banksiana* Lamb.) at wider-than-normal spacing has been carried out in the Lac Seul Forest area since 1988. Preliminary results indicate that survival and stocking are adequate to achieve management goals.

Wide initial spacing and a series of thinnings, along with the promotion of noncrop species, appear to be the correct formula for growing quality sawlogs. As well, thinnings in older jack pine stands hold some promise of producing more sawlogs in a short period of time (5 to 10 years).

## RÉSUMÉ

L'espacement initial et l'éclaircie sont deux éléments essentiels des programmes d'aménagement visant à produire des grumes de sciage de bonne qualité dans les peuplements artificiels et naturels. Depuis 1988, on a planté des épinettes noires (*Picea mariana* [Mill.] B.S.P.) et des pins gris (*Pinus banksiana* Lamb.) à un espacement supérieur à la normale dans la forêt du lac Seul. Les résultats préliminaires indiquent que la taux de survie et la surface occupée répondent aux objectifs de gestion.

Un grand espacement initial et des éclaircies subséquentes, doublés de la promotion des espèces non exploitables, semblent constituer la formule idéale pour l'obtention de grumes de sciage de qualité. Par ailleurs, l'éclaircie des peuplements de pins gris plus anciens semble promettre une production accrue de grumes à brève échéance.

## IN THE BEGINNING

Up until a few years ago, outplanting of all species of bareroot and container planting stock in northwestern Ontario has generally been at 1.5- x 1.5-m or 1.8- x 1.8-m spacings.

The reasons for this are not all known to me. My experience, having planted at these spacing intervals, is that there was a fear of achieving the required stocking and survival that are the measure of a successful plantation: because of this fear, many northwestern Ontario foresters planted at these tight spacings in order to have more seedlings than were required and, thus, a safeguard.

Another reason was the lack of a forest management strategy. There was no detailed plan for growing a forest to meet a specified goal. Each forestry practice was disjoint; for example, we did not attempt to establish a relationship between the spacing at which we planted and the final crop of trees. There was a rhythm to the forestry work that segmented each and every job. We thought in terms of finishing tree planting, for example. Once this was done, it was put into the record books and forgotten.

## THE EVOLUTION OF ONE COMPANY'S STRATEGY FOR FOREST MANAGEMENT

In 1987, the Buchanan Group of Companies had just expanded to four large sawmills and minority ownership in a pulp mill. With this expansion in mill capacity came an increase in our regeneration program. The program involved planting 6 to 8 million trees annually and site preparing 12,000 ha. Because of this increased investment, we began thinking about where we wanted to end up with the program. At this point in time, there were no set goals; we simply completed the annual tasks of regeneration.

The company had medium- to long-term security of wood supply. Most of the long-term wood supply was through our two Forest Management Agreements (FMAs) with the possibilty of two more FMAs in the future. Even with these FMAs, the company derived more than half of its wood supply from licences not controlled by Buchanan. We did not control forest management planning or regeneration practices on these licences.

These circumstances dictated that we concentrate our efforts on the areas where we control planning and regeneration programs. In very simple terms, we had to increase the growth and harvest on our licenses. We started to do this in the Lac Seul Forest by investigating good sawlog stands. Then, with the characteristics of good sawlog stands as the foundation, we prepared a Crop Plan.

## INVESTIGATION OF NATURAL SAWLOG STANDS AND OTHER PROGRAMS

In the Lac Seul Forest, we observed and measured the size and quantity of sawlogs from natural stands to determine the sites and growing conditions that were best for sawlog production. These observations and measurements indicated the preferred tree spacing. We then performed a literature search for research into initial spacing, growth and development of natural stands and plantations, crop planning, spacing effects, wider spacings, thinnings and growth responses to thinnings. This was followed by a number of trips to Vancouver Island and northern Minnesota to observe different approaches to growing sawlogs, beginning with wide initial spacing.

In 1988, we began planting our entire allotment of stock in the Lac Seul Forest at a 2.5- x 2.5-m spacing. We continued this practice in 1989 and 1990. Finally, in 1989, we completed the company Crop Plan, which specified initial spacing, initial density, minimum acceptable survival, frequency and type of thinnings, rotation age, acceptable mortality, final density, and total volume and sawlog volume at rotation age.

## GROWING A SAWLOG FOREST: WHAT THEY LOOK LIKE AND WHAT IS REQUIRED

The best sawlog stands generally consisted of individual, large-diameter (43-cm butt diameter) trees spaced at 4 to 6 m. The stand density of the individual trees varies from 700 to 1200 trees/ha. The number of trees per cubic metre of merchantable wood is 4 to 6. Sawlog stands in our area usually take two forms... jack pine (*Pinus banksiana* Lamb.) or upland mixedwood stands.

The jack pine stands are of fire origin, and begin with densities of 30,000 to 50,000 trees/ha; through natural thinning and mortality, they complete their growth with densities of 700 to 1200 trees/ha.

The upland mixedwood stands consist of a combination of white spruce (*Picea glauca* [Moench] Voss) and balsam fir (*Abies balsamea* [L.] Mill.) or a combination of jack pine and/or white spruce or black spruce (*Picea mariana* [Mill.] B.S.P.) and trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.).

Jack pine, white spruce and black spruce are primary sawlog species; balsam fir, trembling aspen, and white birch are secondary. The secondary species act as "groomers" in that they encourage the primary species to grow with good sawlog characteristics. These characteristics are large butt diameters (a minimum of 25 cm), < 60% taper on a 5-m tree length, > 65% of the total tree length free of branches, and a sound and straight bole.

The manner in which the secondary species improve sawlog characteristics is best explained by observing how white spruce and balsam fir interact. Balsam fir acts as a nurse crop during the early development of the stand, when height growth prevails, and then dies and falls out of the stand when the white spruce reaches maximum height growth. This mortality provides the space needed by white spruce to put on diameter growth.

Stiell and Berry (1973) found that in 50-year-old, unthinned white spruce plantations, the number of trees in the mean diameter class decreases as the stand grows, but that this mean diameter at breast height (DBH) is higher at wide spacings.

White spruce plantations, if overtopped, will survive and eventually outgrow competitors (Rauscher 1984). In one experiment, jack pine, red pine (*Pinus resinosa* Ait.) and white spruce were planted at four different spacings in Manitoba; Bella (1986) concluded that average DBH increased with wider spacing. Evert (1971) reported that mean diameter of a stand increased as growing space increased. This has been the case for all species on all sites.

Planting fewer trees reduces establishment costs and accelerates diameter growth of individual trees, resulting in larger, but fewer, trees at any given age. The age at which Mean Annual Increment (MAI, in board-feet) culminates is strongly affected by initial density. Stand density after thinning strongly affects the pattern of MAI over age. Board-foot yields, which are strongly related to individual tree size, are maximized with relatively low levels of initial density — about 81 established trees/ha, which translates to a 4.5- x 4.5-m planting spacing (Lundgren 1981).

Wambach (1967), in his analysis of initial spacing in red pine plantations, concluded that a wide spacing, with 162 established trees/ha, is economically preferable to a higher density of trees. He suggested that under some conditions, even fewer trees may be desirable.

Smith and Oerlemans (1988) predicted an increase of between 18 and 22% in merchantable volume per tree by age 70 in a natural jack pine stand thinned at age 45 years. Spacing affects not only diameter, but also tree volume.

Some Canadian forest managers rely too heavily on traditional European management concepts; they commonly plant or retain too many trees. With a wider spacing, one should be able to more than double volumes and values from a given investment (Smith 1986).

## A Sawlog Forest in the Making

Over the past 3 years, we have planted 4.6 million seedlings in our Lac Seul Forest FMA (Table 1). All these seedlings were planted at a 2.5- x 2.5-m spacing.

Table 1. Results of 3 years of planting at wide spacing in the Lac Seul Forest FMA.

| Year | Number of trees planted | Site preparation technique | Spacing interval (m) | Planting quality[a] |
|---|---|---|---|---|
| 1988 | 708,600 | 3-row Bräcke | 2.5 x 2.5 | 95% |
| 1989 | 1,935,100 | 3-row Bräcke<br>Light drags | 2.5 x 2.5 | 96% |
| 1990 | 2,000,000 | 3-row Bräcke | 2.5 x 2.5 | 96% |

[a] percentage of seedlings that were planted properly

An equal mix of black spruce and jack pine was planted on each site. Preliminary results, based on field investigations, are that survival and growth are normal or better and there is no reason to think, at this point in time, that we will not achieve our planned results. The spacing interval that was used is just one part of the overall plan to grow a sawlog forest.

Initial spacing control alone cannot produce a sawlog forest; it must be part of an overall plan that follows these principles:

- plant rather than seed to control initial spacing;
- plant at wide spacing;
- plant jack pine;
- maintain nurse crops of hardwoods and balsam fir;
- thin regularly;
- intercede in young stands of fire origin by thinning;
- fertilize on less-productive sites;
- intercede in 55- to 65-year-old jack pine stands by cleaning out understory vegetation, which will accelerate the natural process of increasing diameter growth; and
- concentrate efforts on sites with a high sawlog yield.

These principles are the basis for our company Crop Plan, which details the parameters of regeneration practices.

Our company Crop Plan (Table 2) is designed to produce an optimum log with a butt diameter of 25 cm, ≤ 60% taper on a 5-m log length, > 65% of branch-free log length, and a sound and straight log. We want to grow large-diameter trees in stands with high volumes of sawlogs per hectare and maximize net profitability per hectare of the wood product.

The costs of doing precommercial thinnings are too high to be recovered by the increases in sawlog volume and abundance and the rate of return based on a shorter rotation period. Therefore, we must implement wider initial spacing to allow us to eliminate precommercial thinning.

Another principle of growing sawlogs is to intercede in jack pine stands near their rotation age. We found that in jack pine stands in the 55–65 year age group, trees are crowded. The crop trees are easily recognizable as are the smaller understory and intermediate trees, which will die during the next decade. Our experience is that the crop trees do not put on substantial diameter growth until the smaller understory trees die. We plan to speed this

Table 2. The Buchanan Crop Plan specifications.

| Characteristic | Planned parameters |
|---|---|
| Initial spacing | 2.5 x 2.5 m |
| Initial density | 1482 to 1927 trees/ha |
| Minimum acceptable survival at time of planting | 90% |
| Thinnings | 1st - age 25 years, jack pine to 1500 trees/ha, spruce to 1000 trees/ha<br>2nd - age 35 years, jack pine to 1300 trees/ha, spruce to 900 trees/ha |
| Rotation age | 50 years from time of planting |
| Acceptable mortality | 20% of original number of trees/ha, |
| Final density | jack pine - 1186 trees/ha, spruce - 790 trees/ha |
| Merchantable volume at rotation age | jack pine - 230 $m^3$/ha, spruce - 313 $m^3$/ha |
| Sawlog volume at rotation age | jack pine – 213 $m^3$/ha, spruce – 269 $m^3$/ha, 85% sawlog content |

natural process by thinning the stand. The thinning would involve harvesting the non-crop trees before their death with a small feller-buncher and skidder.

The anticipated results will, we hope, be a shorter sawlog rotation age, a financial recovery of otherwise lost wood material, use of unutilized trees, and an increase in sawlog abundance in the final stand.

The other, more indirect, result is that we want to demonstrate to our accountants and bankers that thinnings are profitable in the long term.

When we prepared the company Crop Plan, our accountants were skeptical. They were particularly concerned about expenditures on thinnings in relation to the anticipated return at rotation age. We hope that by doing this kind of thinning we can convince the accountants that a managed forest pays its own way, so to speak.

## CONCLUSIONS

Spacing and thinning are integral components of an overall strategy to grow forests for the future of northwestern Ontario's forest industry. In the past, there was little consideration of long-term goals, and this led to short-term objectives.

Buchanan has explored the possibilities for increasing and maximizing sawlog content to supply its sawmills. The company decided on a Crop Plan and implemented it in 1988 by planting 4.6 million trees at wider spacings. Initial investigations indicate that these trees will achieve the planned results.

A question remains about tree quality. We are particularly concerned about the number of annual rings per centimetre, the number and size of branches, and the wood's specific gravity. Further studies must be done in these areas.

We have, for too long, concentrated our forestry efforts on cutovers when we are surrounded by natural stands with tremendous potential that require management. One example of a type of natural stand with the potential for sawlog production is the class of jack pine stands younger than rotation age. If these stands are thinned, they can produce more logs. The same can be said for pole-sized and younger jack pine and spruce stands.

In northwestern Ontario, we are grappling with the annual problem of insufficient planting stock. Invariably, we have cutover areas for which planting is the only prescription, but there is insufficient planting stock to attain this goal. Two solutions that will replace this area with an equal volume of wood are to thin developing natural stands and to plant at wider spacing to increase the area planted.

From the research reports I read on this topic, it appears that wider spacing is preferred even in the case of pulpwood production. At closer spacings, the advantages in terms of reduced crown size and stem taper are countered by increased establishment costs and longer rotations or costly precommercial thinning operations.

It is now time for all forest managers to decide on and plan the future of their forests to the end of the rotation. Everyone involved in forestry must understand this and work with conviction to achieve the desired end result.

## LITERATURE CITED

Bella, I.E. 1986. Spacing effects 20 years after planting three conifers in Manitoba. Dep. Environ., Can. For. Serv., Edmonton, Alberta. For. Manage. Note No. 29.

Evert, F. 1971. Spacing studies — a review. Dep. Environ., Can. For. Serv., Ottawa, Ont. Inf. Rep. FMR-X-50. 149 p.

Lundgren, A.L. 1981. The effect of initial number of trees per acre and thinning densities on timber yields from red pine plantations in the Lake States. USDA For. Serv., North Central For. Exp. Stn., St. Paul, Minn. Res. Pap. NC-193. 25 p.

Rauscher, H.M. 1984. Growth and yield of white spruce plantations in the Lake States. A literature review. USDA For. Serv., North Central For. Exp. Stn., St. Paul, Minn. Res. Pap. NC-253. 46 p.

Smith, C.R. and Oerlemans, W.J.A.M. 1988. Ten-year growth response and financial evaluation of commercial strip thinning of jack pine: a case study. Gov't of Can., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-396. 24 p. + appendices.

Smith, J.H.G. 1986. Use of wider spacings to reduce costs and increase volumes and values grown. p. 1-8 *in* Reprint Book, 67th Ann. Mtg., Woodlands Sect., Can. Pulp Pap. Assoc., Montreal, Que.

Stiell, W.M. and Berry, A.B. 1973. Development of unthinned white spruce plantations to age 50 at Petawawa Forest Experiment Station. Dep. Environ., Can. For. Serv., Ottawa, Ont. Publ. No. 1317. 18 p.

Wambach, R.F. 1967. A silvicultural and economic appraisal of initial spacing in red pine. Univ. Minn., Ph.D. Thesis, Microfilm #67-14, 665, Univ. Microfilms Inc., Ann Arbor, Mich. 294 p.

# A COMPANY PERSPECTIVE ON SPACING AND THINNING

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## ABSTRACT

Juvenile spacing and thinning are forest management techniques of increasing interest to E.B. Eddy Forest Products Ltd. Forecast declines in maximum allowable depletion as a result of age-class normalization will demand high yields from managed stands. Permanent sample plots within the 1170 ha of juvenile jack pine (*Pinus banksiana* Lamb.) stands in which the company has carried out spacing to date indicate differences in gross total volume per tree of more than 244% in favor of spaced trees after 7 years. An older trial adjacent to the company Forest Management Agreement areas indicates that further thinnings for pulpwood could occur as early as age 30, if required. However, the economics of both spacing and thinning, as well as the resultant wood quality, will remain concerns until long-term growth and yield data are available.

## RÉSUMÉ

La société E.B. Eddy Forest Products Ltd. s'intéresse de plus en plus à l'espacement et à l'éclaircie des jeunes peuplements en tant que technique d'aménagement forestier. Les prévisions plus faibles en ce qui concerne l'épuisement maximal réalisable, attribuables à la normalisation des classes d'âge, exigera un rendement élevé des peuplements aménagés. Les parcelles-échantillons établies dans le peuplement de 1 170 ha de jeunes pins gris (*Pinus banksiana* Lamb.), où la Société poursuit ses travaux d'espacement, révèlent une amélioration de plus de 244 % du volume brut total par arbre, au bout de sept ans, pour les arbres espacés. Un essai plus ancien à proximité des zones cédées à la Société en vertu de l'entente d'exploitation forestière montre qu'on pourrait procéder à d'autres éclaircies dès l'âge de 30 ans pour le bois de pâte, si besoin est. Toutefois, on ignorera exactement la rentabilité de l'espacement et de l'éclaircie de même que la qualité de bois résultant tant qu'on ne possédera pas de données sur le rendement et la croissance des arbres à long terme.

## INTRODUCTION

E.B. Eddy Forest Products Ltd. is a large, fully integrated producer of lumber, pulp and paper. Its primary mills in northeastern Ontario are at Espanola (bleached kraft pulp) and at Nairn Centre and Timmins (softwood lumber). The principal softwood species is jack pine, derived primarily from company operations on its three Forest Management Agreement (FMA) areas. The FMAs run contiguously from immediately west of Sudbury to just north of Foleyet, and encompass some 16,000 km$^2$.

The company conducts a comprehensive forest management program oriented toward jack pine (*Pinus banksiana* Lamb.). This program includes significant areas of juvenile spacing, primarily after aerial seeding. The extent and results of our spacing efforts will be discussed, as will the potential direction of future efforts.

## DEFINITIONS OF SPACING AND THINNING

E.B. Eddy Ltd. defines spacing of jack pine as the reduction of density, at a juvenile age of 7 to 15 years, to a level of 1900 stems/ha. Superior phenotypes, such as those of trees with straight stems, fine horizontal branches and above-average height and diameter growth, are favored.

Thinning is defined by the company as a reduction of density to 950 stems/ha at the polewood stage (25 to 35 years), recovering pulpwood if the wood is available and marketable, and leaving potential sawtimber. This is not currently an operational practice, but may be required in future to provide short-term supplies of pulpwood and, more particularly, long-term supplies of sawlogs. Economics will be a major consideration.

## RATIONALE FOR SPACING AND THINNING

The primary rationale for spacing and thinning is the projected decline in maximum allowable depletion (i.e., allowable cut) that has been forecast in recent timber management plans. These declines are by no means unique to E.B. Eddy, and are a direct result of the reduced need to accelerate harvesting in certain age classes as age-class distributions approach normality.

The result of this reality, presented in Figure 1, is a requirement to nearly double current yields per hectare from the jack pine forest unit within 40 years — all other factors such as substitution of other species and increased utilization of softwoods from hardwood stands are assumed to remain similar to their present status. Attaining average yields of 190 $m^3$/ha will require optimal growing conditions throughout the rotation. Juvenile spacing of overly dense seeded stands may well become necessary as a routine treatment. However, a dearth of long-term, local growth and yield data makes embracing spacing and thinning programs largely a matter of faith.

## COMPANY PROGRAMS TO DATE

Since initiating treatments in 1982, E.B. Eddy has conducted juvenile spacing on 1170 ha of jack pine in its three FMAs. The majority of the work (Fig. 2) has occurred in the Upper Spanish Forest since 1985, assisted greatly by 50% funding from the Canada–Ontario Forest Resource Development Agreement (COFRDA). The recent demise of COFRDA, coupled with shortfalls in provincial FMA funding, have led to a hopefully temporary suspension of the program in 1990.

Spaced stands have averaged 10 to 12 years of age and 5800 stems/ha (pretreatment density). Post-treatment target density was 1900 stems/ha, equivalent to 2.3-m-square spacing. Virtually all thinning was performed by contractors with brush saws. Production averaged 0.45 ha/person-day, with wide variation as a result of operator experience and attitude rather than pretreatment density. Costs have been in line with the current FMA funding rate of $425.00/ha provided by the 1990–1995 Ground Rules for the Spanish forests.

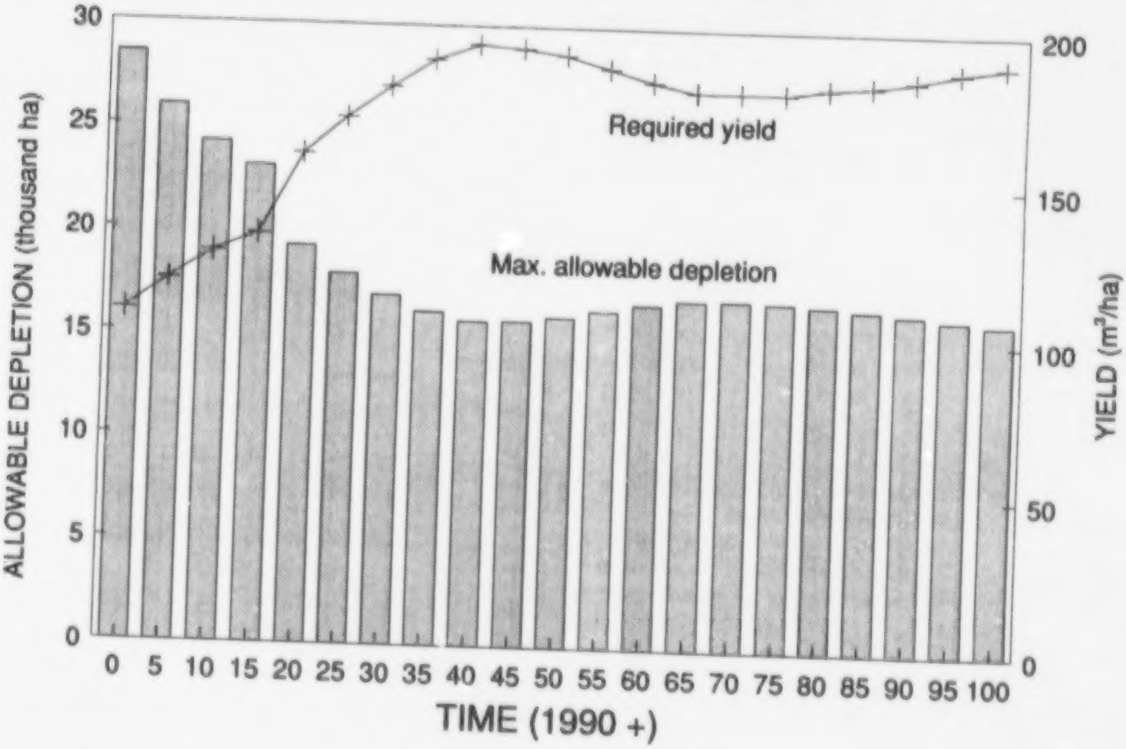

*Figure 1. Projected maximum allowable depletion for the jack pine forest unit, Upper and Lower Spanish Forest.*

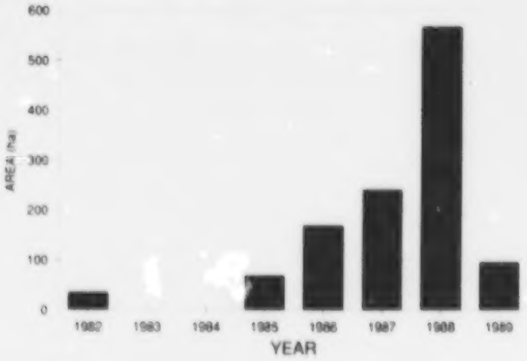

*Figure 2. Summary of jack pine juvenile spacing in E.B. Eddy Forest Management Agreement areas (total area from 1982 to 1989 = 1170 ha).*

No commercial thinnings have been undertaken to date since neither the opportunity (in terms of stands) nor the markets to dispose of thinnings currently exist. However, several small thinned and control permanent sample plots will soon be established in older plantations. This will provide a database to guide potential future programs.

## RESULTS OF JACK PINE SPACING

The short-term results of juvenile spacing can be illustrated with data from permanent sample plots established in E.B Eddy's 1982 thinnings in Carew Township, Upper Spanish Forest. Located along the Ramsey Industrial Road on a deep, fresh, well drained loamy fine sand, the stand was planted and seeded to jack pine by the Ontario Ministry of Natural Resources (OMNR) in 1967. E.B. Eddy conducted spacing operations in 1982 at a stand age of 15 years. Density was reduced from 13,840 stems/ha to 2,016 stems/ha. Dominant, well formed trees were favored.

Three replications of paired treatment and control plots were established in June 1983. Control plots were 0.02 ha each, and treatment plots were 0.04 ha. A complete remeasurement was undertaken in May 1990, the results of which are summarized in Table 1.

The effects of juvenile spacing after 7 years may be summarized as follows, in terms of thinned plots versus controls:

- an 80% reduction in density (Fig. 3),
- a 77% increase in DBH,
- a 10% increase in height,
- a 244% increase in gross total stem volume per tree (Fig. 3), and
- a 51% reduction in gross total volume per hectare.

Table 1. Summary of Carew Township jack pine spacing trial permanent sample plots after one and seven growing seasons.

| | 1983 | | 1990 | |
|---|---|---|---|---|
| Characteristic | Control | Thinned | Control | Thinned |
| Mean density (trees/ha) | 14052 | 2018 | 9390 | 1853 |
| Mean DBH (outside bark, cm) | 3.2 | 5.8 | 5.3 | 9.4 |
| Mean height (m) | 3.69 | 4.97 | 6.54 | 7.19 |
| Mean gross total vol. ($dm^3$/tree) | 1.5 | 6.5 | 7.1 | 24.4 |

Note: all differences between control and thinned means were significant at $p = 0.05$, using a protected least-significant-difference test.

It is interesting to note that the significant increases in diameter, height and volume per tree were initially achieved through the spacing process itself in 1982, as a result of preferential selection of dominant trees. The increased growing space per tree has not yet produced a major relative increase in tree growth, as indicated by a depressed overall gross total volume per hectare in the thinned plots.

However, it is reasonable to expect that volume growth in thinned plots will accelerate on the basis of an older thinning project in Sewell Township, Timmins District. Located along Highway 101 west of Timmins, the site is essentially similar to the one in Carew Township. The pure jack pine stand originated as a result of a 1957 wildfire, and was subsequently spaced by OMNR in 1971 (at 14 years) from a density of greater than 8,000 stems/ha to approximately 3,000 stems/ha. In 1985, 14 years after treatment, E.B. Eddy established two temporary measurement plots in each of an adjacent thinned (Fig. 4a) and unthinned (Fig. 4b) block. The plots straddled the Hydro line immediately north of Highway 101 and comprised about 100 trees each. Total heights and DBHs were recorded.

Gross total stem volumes were estimated from Honer et al.'s (1983) equation, with local company volume tables used for net merchantable volume calculations. The dramatically different volume results are presented in Figure 5, and indicate the following contrasts between thinned and control plots, all in favor of the thinned plot:

- a 311% increase in gross total volume per tree,
- an 11% increase in gross total volume per hectare,
- a 775% increase in net merchantable volume per tree, and
- a 135% increase in net merchantable volume per hectare.

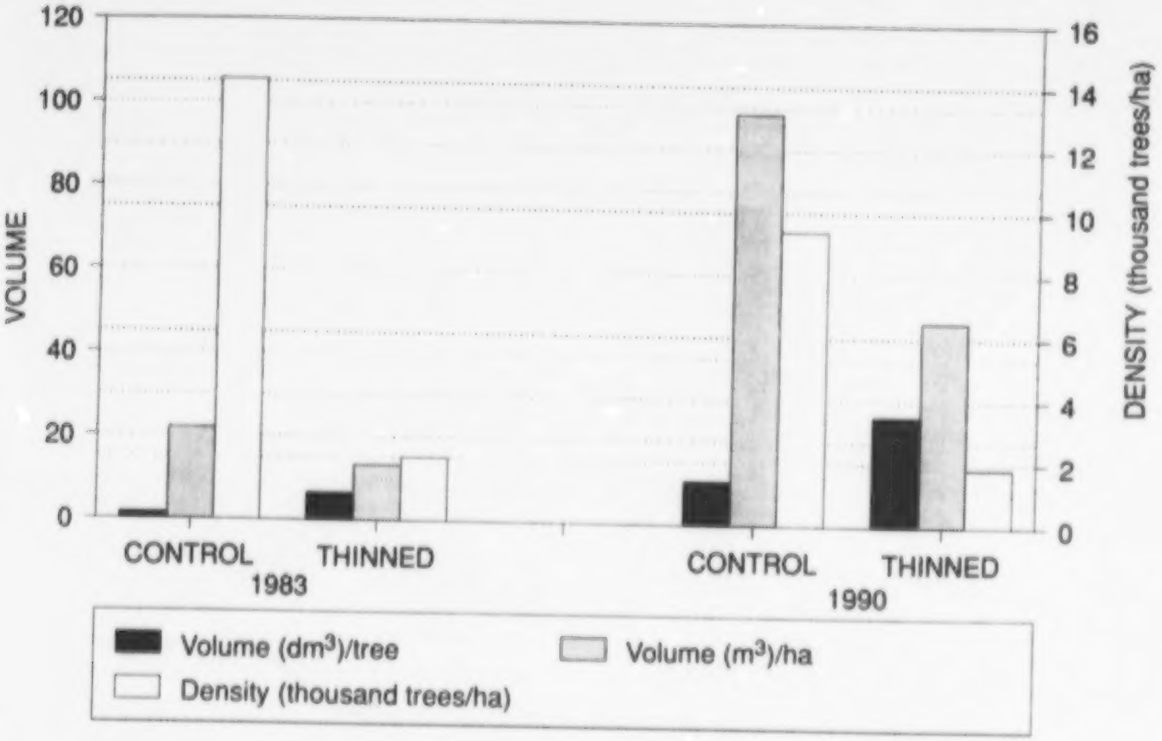

*Figure 3. Volume and tree density in jack pine plots in Carew Township, 1 and 7 years after treatment (thinning). Volumes were calculated by means of Honer et al.'s (1983) equation.*

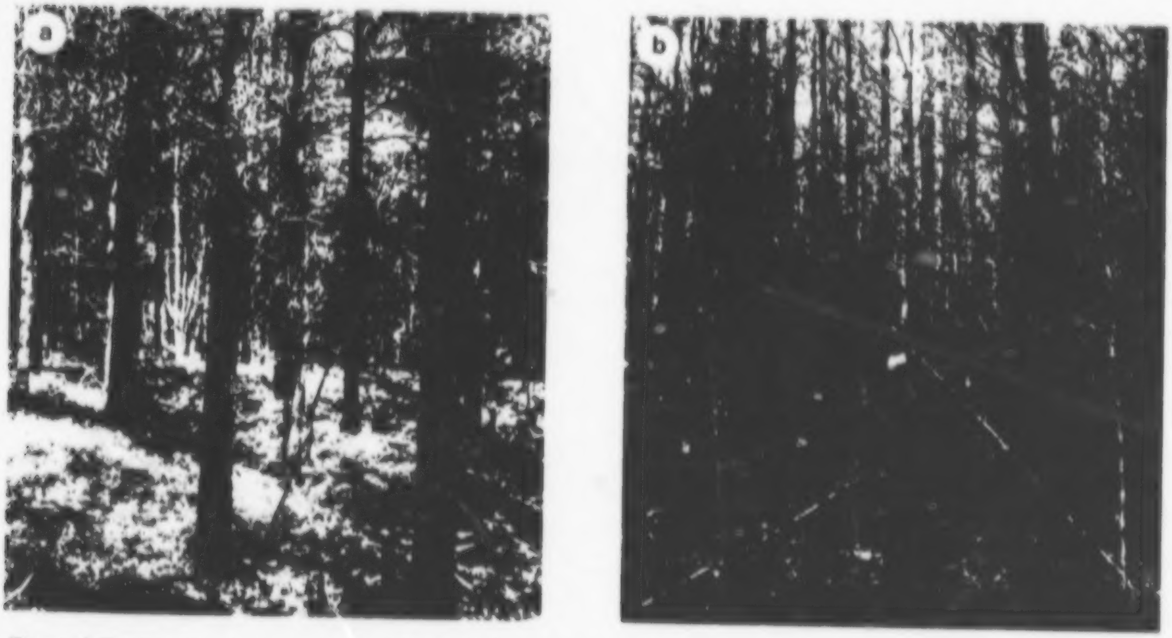

*Figure 4. Temporary measurement plots in the jack pine stand in Sewell Township, Timmins District. (a) thinned, (b) unthinned.*

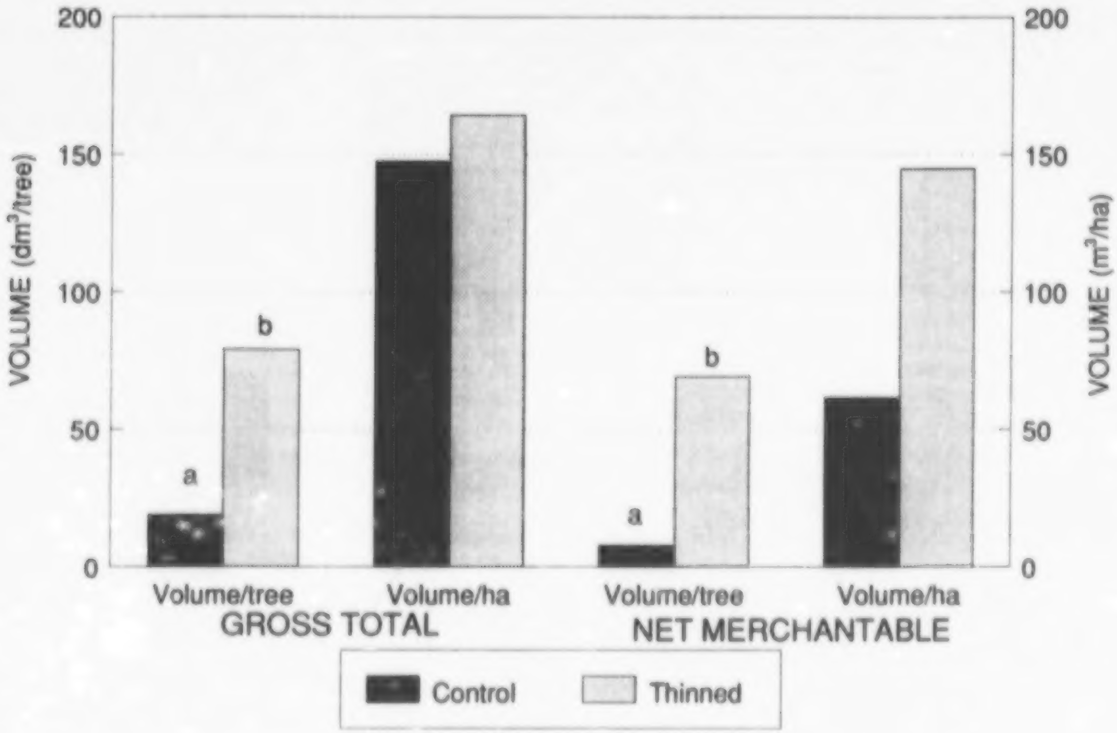

*Figure 5. Volume profile of jack pine plots 14 years after treatment, Sewell Township. ("a" and "b" indicate that the data are significantly different, p = 0.05).*

Crown closure had occurred in the thinned area, on which the equivalent of 145 $m^3$/ha of merchantable pulpwood had developed. A selective commercial thinning to favor potential sawlogs would have been quite possible at this stage, which is cause for optimism concerning the potential of jack pine spacing and thinning in accelerating timber production. The small sample size used in this latter study, however, requires that further study be done on this site. The OMNR Northern Region's Technology Development Unit[1] should be consulted for their more recent findings.

## PERCEIVED PROBLEMS AND NEEDS

Knowledge of the effects of spacing and thinning and the resultant benefit/cost relationships is imperfect. So too are the logistics of implementing such treatments. Specifically, there is a distinct lack of long-term site-specific growth and yield data in relation to spacing and thinning of jack pine in northeastern Ontario. This lack can only be overcome through time, as existing permanent sample plots mature and as new plots are established across a range of sites.

The effects of juvenile spacing and commercial thinning on jack pine wood quality are also largely undetermined. There is a general perception that wide spacing will affect wood quality negatively by resulting in higher proportions of juvenile fiber, increased branch diameter and knot content, and elevated levels of reaction wood. Lumber and pulp manufactured from such material will likely be inferior to current products.

In our experience, stands spaced during their juvenile period are more susceptible to ice and snow damage. The white pine weevil (*Pissodes strobi* Peck) appears to feed preferentially on and lay eggs in the leaders of thinned jack pine, perhaps because of increased leader diameter as a result of more open growth.

A further issue is the lack of demand for pulpwood thinnings, in an era still marked by surpluses of overmature timber. With an ample supply of sawmill chips available, roundwood thinnings hauled from long distances are not cost competitive — at least not without considering the future value of residual sawtimber. Furthermore, the specialized commercial thinning equipment and trained operators required are not readily available.

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The final issue relates to funding. Juvenile spacing by E.B. Eddy has been assisted in the past by grants from COFRDA, to a limit of 50% of actual cost. The current agreement has expired, with no indication of renewal. Furthermore, although an OMNR funding rate has been established under our FMA Ground Rules, financial constraints within the provincial government have precluded any assistance thus far. E.B. Eddy's spacing program is therefore at a (hopefully) temporary standstill.

## POTENTIAL TRENDS IN SPACING AND THINNING

The continuation of juvenile spacing by E.B. Eddy is predicated on three main items:

1) the provision of adequate funding to cover at least 50% of the company's direct costs,
2) a continued positive growth response from spacing that is sufficient to justify the costs, and
3) the continued production of overly dense stands, which require a spacing treatment, as a result of direct seeding.

E.B. Eddy is actually attempting to reduce or eliminate the need for juvenile spacing by combining ground seeding with site preparation. The Bartt Seeder/TTS Delta disc trencher combination was tested in 1989, but with limited success because of design problems with the seeder.

The future of commercial thinning is even more unclear, since there are no local, long-term growth-response data that we are aware of for either plantations or previously spaced areas. Treatment costs will be very high because of the combination of expensive equipment, sites remote from our mills, low-value thinnings and high wage rates. However, the discounted value of the resultant sawlogs may be high enough on some sites to justify the initial cash outlay for thinning.

## SUMMARY

E B. Eddy Forest Products Ltd. is cautiously optimistic about the benefits of spacing and thinning of jack pine. Growth-response information to date suggests that increased sawlog yields and/or reduced rotations are likely on deep, moderately productive, loamy fine sands. Operating and milling costs will most certainly be lower, since wood fiber will be concentrated on fewer and larger trees. Existing permanent sample plots will be followed by the company with great interest to allow us to refine these assumptions.

Concerns remain over the inadequacy of funding for juvenile spacing on Crown lands. Despite the obvious cost advantage of aerial seeding in comparison with planting, the requirement to conduct juvenile spacing afterwards, at a cost of $450.00/ha, justifies some level of funding assistance from government.

Wood quality in thinned stands and their susceptibility to ice and pathogenic damage will also be followed. Commercial thinning trials may be established in the near future to provide insight into long-term stand management. Trials of precision ground-seeding devices will also be continued in an effort to avoid the requirement for conducting juvenile spacing on mechanically site-prepared areas.

## LITERATURE CITED

Honer, T.G., Kerr, M.F. and Alemdag, I.S. 1983. Metric timber tables for the commercial tree species of Central and Eastern Canada. Dep. Environ., Can. For. Serv., Fredericton, N.B. Inf. Rep. M-X-140.

# SESSION III
## Biological Considerations

# THE PHYSIOLOGICAL BASIS OF "SPACE TO GROW"

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## ABSTRACT

The physiological bases for "space to grow" are resource availability and allocation. The three primary resources, light, nutrients and water, each have qualitative and quantitative components. The forest environment is a dynamic arena in which individuals compete tenaciously for these resources, with the goal of survival. Adaptive strategies designed to impart an advantage to the plant rely on a genetic program for implementation. Strategies include: patterns, timing and rate of growth; efficiency in the use of water and nutrients; and tolerance and/or avoidance of stress. The physical expression of trees in a forest stand depends largely on how individuals respond to stress arising from competition for the resource. The result is that trees fall into three operational categories: dominant, codominant and suppressed.

Intensive stand management must optimize the availability of resources to individuals, minimize stress, and ensure that responses are used for growth. Treatments that supplement resources (fertilization and irrigation) or increase resource availability by reducing competition (thinning and vegetation control) enhance growth. To achieve the desired results, the timing and extent of treatment must account for the tree's allocation priorities, tree vigor x treatment relationships must be known for species/site combinations, and management objectives must balance biological benefit and economic gain without threatening long-term productivity of the site.

## RÉSUMÉ

Sur le plan physiologique, l'espace vital est déterminé par la disponibilité et la répartition des ressources. Les trois ressources primordiales (lumière, éléments nutritifs, eau) sont affectées de valeurs qualitatives et quantitatives. Le milieu forestier est une arène où chaque sujet combat pour l'obtention de ces ressources, afin de survivre. Les stratégies d'adaptation visant à conférer un avantage à la plante sont mises en œuvre par un programme génétique. Ces stratégies comprennent les modalités, et la vitesse de croissance ainsi que le choix de moment de cette dernière; l'efficacité de l'emploi de l'eau et des éléments nutritifs; la tolérance, l'évitement ou les deux face aux traumatismes. Dans un peuplement, l'aspect physique des arbres dépend, dans une large mesure, de la réponse de chaque sujet aux traumatismes suscités par la lutte pour l'emploi des ressources. Les arbres entrent alors dans trois catégories: les dominants, les codominants et les dominés.

L'aménagement intensif des peuplements doit optimaliser les ressources disponibles pour chaque sujet, réduire les traumatismes au minimum et faire en sorte que les réactions de chaque arbre servent à son accroissement. Les traitements complémentaires aux ressources (fertilisation ou irrigation) ou augmentant la disponibilité de ces dernières par réduction de la concurrence (coupes d'éclaircie et lutte contre la végétation adventice) bénéficient à l'accroissement. Pour achever les résultats désirés, le choix du moment et l'ampleur du traitement doit se fonder sur des priorités de l'arbre; les rélations entre la vigueur et les traitements doivent être compris pour des combinaisons des espèces et des stations; et les objectifs d'aménagement doivent faire une balance entre l'avantage biologique de l'espèce et le gain économique sans menacer la productivité de la station à long terme.

## INTRODUCTION

What occurs when forest managers modify stand structure? What factors need to be considered to ensure stand-treatment decisions are effective, both biologically and financially? How can our investment in the forest be optimized? These questions reflect the type of information managers should have to make informed decisions about intermediate stand treatments.

This paper presents information that will help increase the resource manager's awareness of tree/stand response so that a better prediction of treatment outcomes is possible. The discussion focuses on the physiological factors responsible for growth responses. By understanding the functional relationships among site, species strategies and resource competition, managers can develop treatments that meet management objectives by optimizing resource use.

## THE FIGHT FOR RESOURCES

Stand manipulation can facilitate the crop tree's fight for resources (Oliver and Larson 1990). Light, water and nutrients are key resources. The primary consideration is to make these resources more readily available to the crop species. Availability depends largely on site quality, resource competitors, and the strategies evolved by the crop species to deal with site and competitor constraints.

### Site Quality

Site quality refers to abiotic factors, including soil type and texture, organic matter, topography and climate. Site extremes increase the risk to crop establishment and growth (Daniel et al. 1979, Larcher 1983, Bloom et al. 1985). Although productive sites have few resource limitations, they accommodate many resource competitors that limit resource availability for the crop species. As sites become less productive, the frequency of resource competitors decreases. There is no corresponding increase in resource availability because site quality is poor. Poorer sites are frequently associated with increased frequency and/or severity of environmental extremes, complicating crop success.

Treatments that supplement resources (fertilization or irrigation) or increase their availability (thinning or vegetation control) have a proportionately greater effect on moderate to poor sites than on good sites, even though the absolute growth response is less (Walstad and Kuch 1987, Newton and Preest 1988). This has important implications for the allocation of funds for intensive management. For example, it may be more cost effective to spend limited silvicultural dollars on a moderate site close to the mill than on a good site farther away.

### Resource Competitors

Competitors are of three primary types: vegetation, animals and micro-organisms. Competition is for light, water and nutrients, and occurs both above and below ground. Although the manner in which competition is expressed varies greatly, competition invariably imposes a stress on the crop species. Stress weakens a crop tree's ability to capture or retain its niche and may increase its susceptibility to previously non-threatening resource competitors.

### Vegetation

Competing vegetation limits the availability of resources to crop species. Trees and brush alter the quality and quantity of the light that reaches the foliage of crop species, and limit the availability of water and nutrients by direct belowground competition. Grasses and herbs are tenacious competitors for water and nutrients, having the same effect on crop-tree productivity as competing trees and/or brush (Wagner 1985, Walstad and Kuch 1987). The competitive nature of grasses and herbs results from the disproportionate root:stem ratio; root biomass frequently exceeds 90% of the total (Larcher 1983, Grime 1979). However, except for germinants and small seedlings, grasses and herbs do little to limit light availability.

The impact of grass and herb competition on crop-tree performance is presented in Figure 1 (DeYoe and Dunsworth 1988). Control of competing vegetation over a range of densities (0, 60, 80, 90 and 100%) and durations (0, 1, 2 and 3 years) has dramatic effects on resource availability and growth (e.g., water; Fig. 2). A financial evaluation can demonstrate the economic benefits of intensive competition control, since up-front costs can be discounted over a shorter rotation period.

As plantations develop from seedlings to mature trees, competition becomes more subtle and may extend over many years as individuals, vying for position, achieve dominance or are suppressed. Regardless of the species or species mix, the growth of individuals in stands is governed largely by microsite conditions and the decline or mortality of nearest neighbors (Daniel et al. 1979, Peet and Christensen 1987, Oliver and Larson 1990). Enhancing resource availability for individuals by thinning or fertilizing has dramatic effects on individual productivity, even though overall stand production remains relatively stable because of limits on the site's carrying capacity (Daniel et al. 1979, Klinka et al. 1990, Stathers et al. 1990).

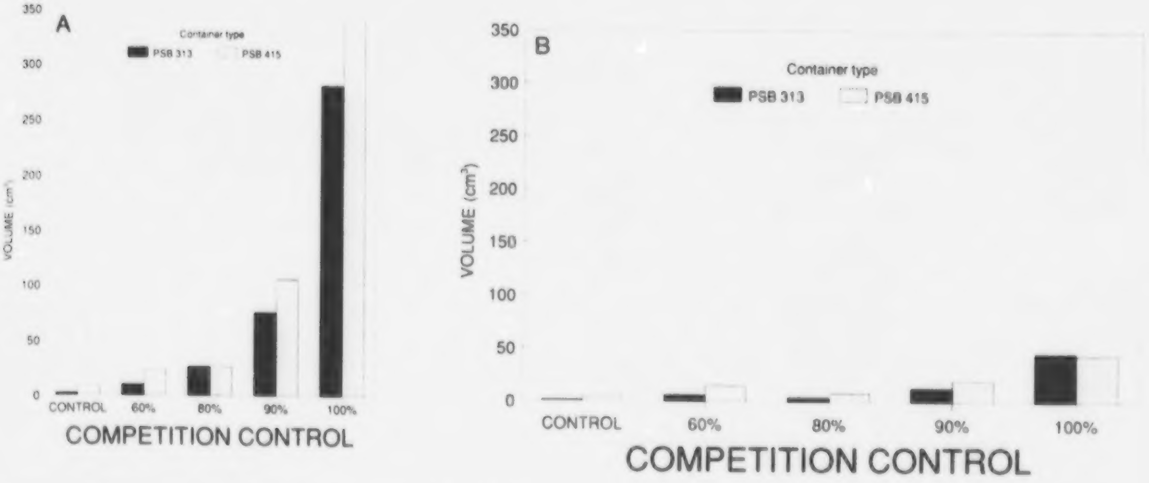

*Figure 1. Douglas-fir (*Pseudotsuga menziesii *[Mirb.] Franco) volumes after 3 consecutive years (A) and 1 year (B) of weed control.*

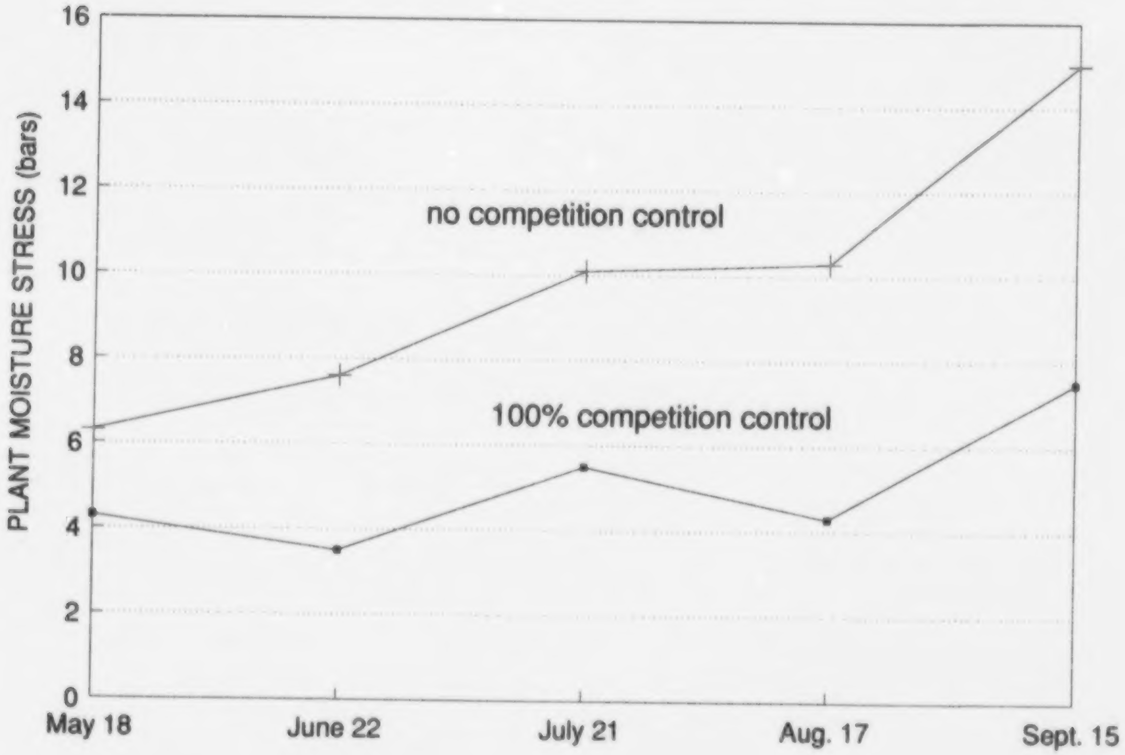

*Figure 2. Plant moisture stress after 3 years for seedlings with 100% weed control and no weed control over a 3-year period.*

### Animals

Animals can be divided into three categories, "Nippers" (deer, moose, grouse, etc.), "Clippers" (gophers, beavers, rabbits, etc.), and "Strippers" (mice, squirrels, porcupines, etc.), on the basis of how resource acquisition is expressed. Animals acquire carbon-based foods and nutrients by consuming vegetation — including crop trees. The damage caused by animals in intensively managed plantations can be substantial, since crop trees tend to be readily accessible and nutritionally rich (DeYoe et al. 1985, Sullivan et al. 1990).

Animals such as gophers, porcupines, elk, bears, beavers and squirrels can cause severe damage to saplings and/or mature crop trees. This damage stresses (or kills) the tree, increasing its susceptibility to damage by micro-organisms and endangers its position in the stand.

As management practices become increasingly intensive at the plantation or stand level, it is important to develop programs to prevent animal damage and diffuse potential problems. Frequently, this can be achieved by understanding the nature of the animal and ensuring that management practices do not inadvertently create conditions preferred by the animal.

### Micro-organisms

Fungi and insects are the principal competitors, although many other organisms that use trees as a source of resources to survive and carry out their function in the forest ecosystem. Although fungi and insects can attack healthy trees, most species affect trees previously stressed by abiotic or biotic factors. This is a primary mechanism by which nature regulates the overall health of the forest ecosystem (Hoque 1982, Bazzaz et al. 1987, Franklin et al. 1987). However, at the stand level, their presence is often perceived as a detriment to financial security. One exception is mycorrhizae. Fungi of this group form symbiotic relationships with tree roots, acquiring carbon substrates for sustenance while facilitating acquisition of water and certain nutrients by the tree (DeYoe 1983).

The principal impact of fungi and insects is their effect on the tree's allocation priorities. Resource demands caused by micro-organisms, or by animal damage, shifts the tree's allocation of resources to the source of the activity or injury. These resources (water, nutrients) are now used to repair damage and relieve stress instead of supporting growth and development, as would be the case in the absense of stress (Hoque 1982, Bloom et al. 1985, Bazzaz et al. 1987).

The financial investment in controlling diseases and/or insect infestations is considerable. Although intensive management can disrupt the sensitive balance between predator and host, the manager's ability to maintain tree vigor can drastically reduce the impact of these micro-organisms on tree/stand productivity. Marginal attempts at intensive management, however, may do just the opposite.

### Species Strategies

Species strategies involve genotypic factors intrinsic to each species that determine how the species adapts to site and competitor conditions within or characteristic of its natural range. There are strategies for growth and development, stress response and opportunism (Levitt 1980a,b; Larcher 1983; Gale and Zeroni 1985; Waring and Schlesinger 1985).

### Growth and Development

Spatial and structural patterns, timing, rate, and type of growth describe the framework within which an array of strategies may exist (Levitt 1980a,b; Larcher 1983). For example, for a species to gain a competitive edge after a disturbance, it should have the following capabilities: growth initiation early in the growing season (timing), rapid height growth (rate), expansive lateral branching (structural pattern), vigorous sprouting (type), and the ability to be a microsite generalist (spatial pattern). These attributes are important for capturing a site, becoming established, and gaining dominance, i.e., for cornering the resource market! Once cornered, tree vigor is increased, and more emphasis can be placed on mechanisms that provide protection from abiotic or biotic stresses.

### Stress Strategies

Stress occurs when an environmental signal, because of its timing, duration, intensity or frequency, limits or alters plant functions associated with growth and development. The stress signal imparts a message to the plant's genome and initiates a series of physiological changes that shift plant functions from growth and development to adjustment and repair, followed by recovery (Levitt 1980a,b; Hoque 1982; DeYoe 1990).

Trees use three basic mechanisms to deal with stress: evasion, avoidance and/or tolerance (Levitt 1980a,b). For the example of drought stress, an evader will simply drop its leaves to minimize water loss; acute drought stress may kill the aboveground portion of the tree, triggering expression of various types of vegetative growth (e.g., sprouting, suckering, layering) when water becomes more readily available. Avoiders close their stomates to conserve water and place a high priority on root expansion and mycorrhizal associations to improve access to water (Levitt 1980b); tolerators add solutes to the cell solution to bind water tighter than the "drought forces" trying to pull it away (Levitt 1980b).

Unfortunately, stress is cumulative. Each stress event elicits a similar physiological response, further diverting the tree from a "wood production" mode (Chapin et al. 1987, DeYoe 1990). Consequently, stressed trees, although responsive to treatment, respond to meet their own objectives (adjustment, repair and recovery), not the manager's (volume growth). For example, if a stand is already stressed as a result of neglect, thinning may result in prolic foliar or fine-root development, with little or no volume response. This could lead the manager to misinterpret the treatment as ineffective for the site or species in question.

### Opportunistic Strategies

Two opportunistic strategies used by some plants to gain a competitive edge are allelopathy and carnivory. Allelopathic species release a liquid or gaseous substance toxic to competitors (Rice 1983), enabling the species to reduce the competitiveness of its nearest neighbors and place itself in a more advantageous position for gaining limited resources, including the site itself. Carnivory is not a trick used by commercial tree species to eliminate competitors; however, it is an interesting thought for a genetic engineer looking for a new twist.

## MANAGEMENT OBJECTIVES — TREES VS. MANAGERS

What are your management objectives? Whether the objective is salvaging mortality, obtaining larger piece sizes or shorter rotations, minimizing losses to disease or insects, compensating for a long-term wood supply gap, or simply taking advantage of a current market demand, clear and concise objectives are essential to improve the benefit:cost ratio of an investment. Until the objectives are well articulated and a plan designed to meet those objectives is in place, the probability of failure is high. Planning must account for the current condition of the crop species in relation to site conditions, competing species and strategies for gaining a competitive edge.

There are many silvicultural treatments available for achieving management objectives. However, if the condition of the crop trees is unknown, then the risk associated with attaining the desired treatment effect is high. A precise assessment of crop status is not practical; however, understanding the factors that affect resource availability and the strategies used by the crop tree to establish and maintain favorable growth can minimize the risk of inappropriate decisions.

Intensive treatments must be applied before crop trees sustain significant site- or competitor-induced stress. This will (1) minimize the risk of shock from the treatment, (2) minimize the time and cost of achieving the desired result, and (3) focus the use of limited resources on growth rather than on adjustment, repair and recovery.

## RESOURCE BALANCING

Trees have an internal hierarchy for allocation of resources that is based on intrinsic priorities established through evolutionary adaptation to a range of sites and competitors inherent to their natural range (Table 1).

Table 1. Carbohydrate and nutrient allocation priorities in response to stress.

| Stress | Priority | Response |
|---|---|---|
| high | survival | buds and new foliage, fine roots |
| | reproduction | "fail safe" (developmental shift to new structures) |
| medium | maintenance and recovery | storage reserves: stem, canopy and roots |
| | growth | shoot/root extension |
| low | growth | shoot/root diameter increase |
| | protection | protective chemicals or structures |

### Priorities

A tree's priorities are survival, reproduction, maintenance of reserves, growth and protection (Waring and Schlesinger 1985). Morphology represents the physiological expression of these functional priorities. To ensure survival, trees place a high priority on the development of leaf area (buds and new foliage) and fine roots. Reproduction is important as a "fail safe" strategy, more closely linked to species than individual survival. The conservation of storage reserves in canopy, stem and roots, though of moderate priority, provides insurance for seasonal or annual limitations in resource availability and has important implications for stress responsiveness and recovery. Shoot and root extension growth, though not essential for survival, are important to managers. Volume production and tree vigor are even more important in intensive management programs. Vigor allows for the production of protective chemicals and structures that provide mechanisms to avert moderate abiotic or biotic stress conditions. The tree, on the other hand, places a low priority on these attributes because they require substantial resources to develop and maintain.

Further, most adaptive mechanisms only offer a first line of defence against moderately acute stress rather than the chronic stresses more typical of less intensively managed forests.

## Balance Indicators

The tree uses its carbon (C) and nitrogen (N) balance (C/N) as an indicator of where resources must be allocated to maintain a balance that optimizes its ability to remain dominant on the site. The C/N balance is a function of the tree's allocation priorities for survival; it is a useful measure because C and N are the "chemical ingredients" needed in greatest quantity by the tree to support structural and functional requirements (Bloom et al. 1985, Waring and Schlesinger 1985, Bazzaz et al. 1987). Although it is commonly believed that trees seek water, in fact, trees use water to expand root systems to acquire nutrients. Trees under poor nutrient conditions will, over time, use available water to develop more expansive root systems to meet nutritional demands (Levitt 1980b, Larcher 1983, Waring and Schlesinger 1985, Stathers et al. 1990). Further, trees on nutrient-poor sites cycle nutrients internally and reclaim nutrients from deciduous parts (leaves, fine roots, etc.) before they are shed. There is also a tendency to retain leaves and roots longer. Trees on nutrient-rich sites use what is needed to support growth requirements, then release the excess and/or pre-empt nutrient retention by shedding leaves and avoiding the high energy costs of export. When carbon levels are low, the tree emphasizes production of leaf and branch structures to improve the efficiency of light capture. An individual's position in the canopy determines the physiological characteristics of its leaves in using light of varying quality and intensity (Boardman 1977, Levitt 1980b, Larcher 1983). Conversely, if N levels are low, the tree emphasizes production of root structures so that more N can be extracted from the soil. In summary, if N is low, the tree grows roots and increases mycorrhizal associations; if C is low, it develops its crown.

## The Balancing Act

The physiological C/N relationship has a profound effect on allocation of the tree's resources and the development of structures (biomass) to facilitate acquisition of new resources (Larcher 1983, Waring and Schlesinger 1985, Bazzaz et al. 1987, Chapin et al. 1987, Stathers et al. 1990). Figure 3 depicts the allocation pattern representative of a site/species relationship under the site conditions described. Table 2 provides a specific example for a subalpine community in the Cascade Mountains of Washington, where sites are characterized by short growing seasons; shallow, nutritionally poor soils; cold winters with a substantial snow pack; and generally moist conditions throughout summer. Detritus decomposes slowly, leading to the development of thick, persistent organic layers on less exposed sites. A striking feature is the amount of biomass allocated annually to fine-root production. For this ecosystem, nutrients, not water or light, are limiting (Grier et al. 1981).

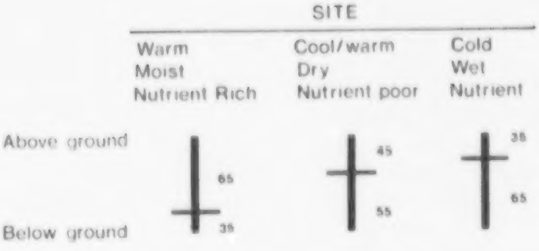

*Figure 3. The influence of limiting resources (stress) on annual allocation of aboveground and belowground biomass.*

Table 2. An example of a tree's allocation stategies at various levels.

| System level | Characteristics |
|---|---|
| Ecosystem | Pacific silver fir (Abies amabilis [Dougl.] Forbes), 3500 ft. (1050 m) above sea level, north-central Cascades range, Washington state; cold, wet, nutrient-poor site. |
| Individual balance | 120-year-old stand, 25% of biomass above ground, 75% below ground. |
| Tissue priority | New primary production of fine roots is 66% of total carbon allocation. |
| Cellular controls | C/N balance — allocation of structural/functional chemicals. |

Modification of a microsite to enhance the availability of resources for crop trees results in reallocation of resources for growth to meet the tree's balance needs (Axelsson 1981, Bazzaz et al. 1987, Waring and Schlesinger 1985). Whether the tree is stressed or vigorous will determine how the "survival related" priorities are invoked (Table 1). The more vigorous the tree, the greater the emphasis on growth and accumulation of protective compounds/structures. If nutrients are readily accessible, growth will be channeled to the crown; however, if the root system is unable to supply the nutrients, or if there has been a nutrient deficiency, root system expansion will likely take precedence.

Figure 4 provides an example of how increasing the availability of resources by thinning and/or fertilization affects the production balance between shoots and fine roots for a tree growing on a moderately good, mesic site (Axelsson 1981). The increased availability of nutrients and water clearly demonstrates the "productivity" benefits of silvicultural treatments.

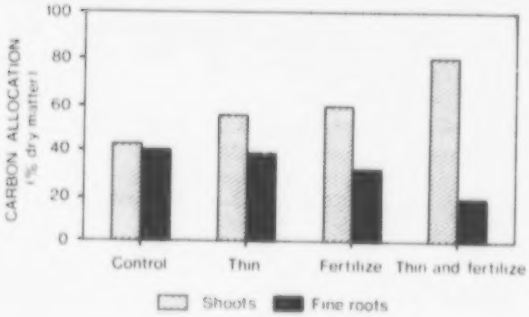

*Figure 4. Allocation of dry matter between roots and shoots in response to thinning, fertilization, and thinning and fertilization. (Note: totals may not add to 100% because other components of total biomass are not included.)*

Although dramatic, these responses would be diminished substantially in stands under chronic stress as a result of silvicultural neglect or a more extensive approach to management. Consequently, investments in intensive treatments should only be done if they are likely to meet the management objective or to minimize some risk.

## A MANAGEMENT SCENARIO — THE REAL WORLD

A series of questions, matched with hypothetical responses, is presented to illustrate the type of decision that may be necessary.

1 Why perform an intensive stand management treatment?
   - It's part of a recently imposed intensive management plan for the site in question.
2 What precisely do you hope to achieve?
   - I want to maintain mean annual increment (MAI) at or above level "X" to generate volume "V" and basal area "B" by harvest in 2010, and minimize risk of bark beetle damage.
3 What is the current condition of the trees/stand?
   - MAI is poor, and the stand has a low growth efficiency index, indicating stress. Bark beetle damage is evident in the area, but is not yet serious.
4 What treatment best addresses "biological" objectives within an acceptable economic framework, given current stand conditions?
   - Best option: thin in 1991, fertilize in 1995, thin in 2005, and harvest in 2010.
5 Can you afford it?
   - No option delivered a positive net present value. The best option will minimize bark beetle risk, but not achieve the growth objective.

The decision is to thin and fertilize because there are high-risk areas already under bark beetle attack near the existing stand. A decision to do less risks heavy mortality in the stand and enhances its susceptibility to fire. Had the stand been precommercially thinned earlier in stand development, vigor could have been maintained and growth objectives met under the intensive regime. Although the expenditure will incur a loss, it is less than that of losing the stand to insects or fire.

The point to remember is that intensive stand management is not an "on again, off again" proposition. It begins with a plan that covers the period between harvests. Its primary purpose is to maintain stand vigor at a level that ensures the manager's productivity target will be met. If availability of resources is inadequate to meet vigor requirements because of competition, and if stand condition deteriorates, treatment effectiveness will diminish and the manager's return on investment will be lost.

## LITERATURE CITED

Axelsson, B. 1981. Site differences in yield, differences in biological production or in redistribution of carbon in trees. Swedish Univ. Agric. Sci., Dep. Ecol. Environ. Res., Uppsala. Res. Rep. No. 9.

Bazzaz, F.A., Chiariello, N.R., Coley, P.D. and Pitelka, L.F. 1987. Allocating resources to reproduction and defense. Bioscience 37:58–67.

Bloom, A.J., Chapin, F.S. III and Mooney, H.A. 1985. Resource limitations in plants — an economic analogy. Ann. Rev. Ecol. Syst. 16:363–392.

Boardman, N.K. 1977. Comparative photosynthesis of sun and shade plants. Ann. Rev. Plant Physiol. 23:355–377.

Chapin, F.S. III, Bloom, A.J., Field, C.B. and Waring, R.H. 1987. Plant responses to multiple environmental factors. Bioscience 37:49–56.

Daniel, T.W., Helms, J.A. and Baker, F.S. 1979. Principles of silviculture. McGraw-Hill, N.Y. 500 p.

DeYoe, D.R. 1983. Mycorrhizae: a hidden benefactor to forest trees. Oregon State University Extension Serv., Corvallis. Rep. EM-8247. 11 p.

DeYoe, D.R. 1990. Stress and seedlings: concepts and assessment technology. p. 49-58 *in* J. Burley, *Ed.* XIXth IUFRO Congr. Division 2 — Stress physiology. Canadian IUFRO World Congress, 5-11 August 1990, Montreal, Que.

DeYoe, D.R., deCalesta, D. and Schaap, W. 1985. Understanding and controlling deer damage in young plantations. Oregon State Univ. Extension Serv., Corvallis. Rep. EC-1201 15 p.

DeYoe, D.R. and Dunsworth, B.G. 1988. Duration and intensity of vegetation control: establishing seedling growth potential. p. 10 *in* Proc. 3rd Ann. Vegetation Management Workshop, Vancouver, B.C.

Franklin, J.F., Shugart, H.H. and Harmon, M.E. 1987. Tree death as an ecological process. Bioscience 37:550–556.

Gale, J. and Zeroni, M. 1985. The cost to plants of different strategies of adaptation to stress and the alleviation of stress by increasing assimilation. Plant Soil 89:57–67.

Grier, C.C., Vogt, K.A., Keyes, M.R. and Edmonds, R.L. 1981. Biomass distribution and above- and below-ground production in young and mature *Abies amabilis* zone ecosystems of the Washington Cascades. Can. J. For. Res. 11:155–167.

Grime, J.P. 1979. Plant strategies and vegetation processes. John Wiley and Sons, N.Y. 222 p.

Hoque, E. 1982. Biochemical aspects of stress physiology of plants and some considerations of defense mechanisms in conifers. Eur. J. For. Pathol. 12: 280–296.

Klinka, K., Feller, M.C., Green, R.N., Meidinger, D.V., Pojar, J. and Worrall, J. 1990. Ecological principles: applications. p. 55-73 *in* D.P. Lavender, R. Parish, C.M. Johnson, G. Montgomery, A. Vyse, R.A. Willis and D. Winston, *Ed.* Regenerating British Columbia's forests. Univ. British Columbia Press, Vancouver.

Larcher, W. 1983. Physiological plant ecology. Springer-Verlag, Berlin. 303 p.

Levitt, J. 1980a. Responses of plants to environmental stresses. I. Chilling, freezing, and high temperature stresses. Academic Press, N.Y. 497 p.

Levitt, J. 1980b. Responses of plants to environmental stresses. II. Water, radiation, salt and other stresses. Academic Press, N.Y. 606 p.

Newton, M. and Preest, D.S. 1988. Growth and water relations of Douglas-fir (*Pseudotsuga menziesii*) seedlings under different weed control regimes. Weed Sci. 36:653–662.

Oliver, C.D. and Larson, B.C. 1990. Forest stand dynamics. McGraw-Hill, N.Y. 467 p.

Peet, R.K. and Christensen, N.L. 1987. Competition and tree death. Bioscience 37:586–595.

Rice, E.L. 1983. Allelopathy. 2nd ed. Academic Press, N.Y. Monograph 83–11782.

Stathers, R.J., Trowbridge, R., Spittlehouse, D.L., Macadam, A. and Kimmins, J.P. 1990. Ecological principles: basic concepts. p. 45-54 *in* D.P. Lavender, R. Parish, C.M. Johnson, G. Montgomery, A. Vyse, R.A. Willis and D. Winston, *Ed.* Regenerating British Columbia's forests. Univ. British Columbia Press, Vancouver.

Sullivan, T.P., Harestad, A.S. and Wikeem, B.M. 1990. Control of mammal damage. p. 302-318 *in* D.P. Lavender, R. Parish, C.M. Johnson, G. Montgomery, A. Vyse, R.A. Willis and D. Winston, *Ed.* Regenerating British Columbia's Forests. Univ. British Columbia Press, Vancouver.

Wagner, R.G. 1985. Effects of intensive vegetation management on survival and growth of Douglas-fir seedlings in the Coast Range of Oregon and Washington. Oregon State Univ., Corvallis. CRAFTS Rep.

Walstad, J.D. and Kuch, P.J. *Ed.* 1987. Forest vegetation management for conifer production. John Wiley and Sons, N.Y. 523 p.

Waring, R.H. and Schlesinger, W.H. 1985. Forest ecosystems: concepts and management. Academic Press, Orlando, FL. 340 p.

# SPRUCE BUDWORM DEFOLIATION IN YOUNG SPACED AND UNSPACED BALSAM FIR STANDS

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## ABSTRACT

Defoliation and spruce budworm (*Choristoneura fumiferana* [Clem.]) population levels were estimated annually in young spaced and unspaced balsam fir (*Abies balsamea* [L.] Mill.) stands from 1976 to 1984 during a spruce budworm outbreak in the Cape Breton Highlands, Nova Scotia. There were no significant differences in the extent of defoliation between spaced and unspaced trees as long as only the current foliage was defoliated; infestation levels were up to about 30 and 15 sixth-instar larvae per branch tip for spaced and unspaced trees, respectively. Significantly higher defoliation occurred in the spaced stands in 1977, 1978 and 1980, under conditions of extreme budworm population densities; defoliation was characterized by destruction of the current foliage combined with severe backfeeding on older age classes of needles. Consequently, by the end of the spruce budworm outbreak, budworm-caused mortality averaged 44% in spaced stands and 19% in unspaced stands.

## RÉSUMÉ

On a évalué chaque année la défoliation et la population de tordeuses des bourgeons de l'épinette (*Choristoneura fumiferana* [Clem.]) dans les jeunes peuplements espacés et non espacés de sapins baumiers (*Abies balsamea* [L.] Mill.) entre 1976 et 1984, sur les hauts plateaux du Cap Breton, en Nouvelle-Écosse. On n'a observé aucun écart significatif dans le degré de défoliation des arbres espacés et non espacés tant que le feuillage de l'année est le seul attaqué; le taux d'infestation se chiffrait respectivement à environ 30 et 15 ravageurs (sixième instar larvaire) par branche (extrémité) pour les arbres espacés et non espacés. On a cependant noté un degré de défoliation sensiblement plus élevé dans les peuplements espacés en 1977, 1978 et 1980, années où la population de tordeuses était particulièrement élevée. La défoliation se caractérise par la destruction du feuillage de l'année, combinée à une forte destruction des aiguilles d'âge plus ancien. À la fin de l'infestation, le taux de mortalité attribuable aux ravageurs se situait donc en moyenne à 44 % dans les peuplements espacés et à 19 % dans les peuplements non espacés.

## INTRODUCTION

The possibility of increased insect defoliation in spaced, thinned and planted coniferous stands has generated considerable interest in recent years as forest companies and government agencies are expanding their silviculture programs. The susceptibility and vulnerability of various forest stands to insect damage have been studied almost exclusively in unmanaged forest defoliated by the spruce budworm (*Choristoneura fumiferana* [Clem.]); for a review of this subject, see MacLean (1980) and Blum and MacLean (1985). In general, these studies indicate that host susceptibility increases with increasing percent crown closure and proportion of host species (Fauss and Pierce 1969) and decreases for faster-growing trees (Craighead 1925, Kleinschmidt et al. 1980) and increasing levels of non-host species (Blais 1958, Fauss and Pierce 1969, Crook et al. 1979).

Opening up stands by spacing and thinning does not increase stand susceptibility to spruce budworm defoliation (Crook et al. 1979), and may, in some instances, actually decrease defoliation levels (Batzer 1967). An exception is in mixedwood stands when the silviculture treatment removes the protecting cover, thus augmenting the intensity of attack on the residual host species (Crook et al. 1979).

Studies with other insect species indicate that thinned lodgepole pine (*Pinus contorta* Dougl.) attacked by the lodgepole terminal weevil (*Pissodes terminalis* Hopk.) and more open plantations of Sitka spruce (*Picea sitchensis* [Bong.] Carr.) damaged by the Sitka spruce weevil

(*Pissodes strobi* Peck) exhibited increased incidences of attack (Bella 1985, Alfaro and Omule 1990). However, thinned stands of lodgepole pine were less susceptible to attack by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) than were untreated stands (Mitchell et al. 1983).

The main objective of this report is to compare spruce budworm defoliation in young spaced and unspaced balsam fir (*Abies balsamea* [L.] Mill.) stands. Detailed defoliation measurements of trees were taken throughout a spruce budworm outbreak; this was part of a larger study relating spruce budworm defoliation to growth loss (Piene et al. 1981, Piene 1989).

## METHODS AND MATERIALS

The study area was located in the Cape Breton Highlands, Nova Scotia, in a 25- to 30-year-old, almost pure balsam fir forest. For a detailed description of the study area and methods, see Piene et al. (1981) and Piene (1989). In 1971, part of this forest was thinned to a spacing of 2.4 x 2.4 m by Stora Forest Industries. A severe spruce budworm outbreak started on the northwestern coast of the Cape Breton Highlands in 1974 (Forbes et al. 1975) and reached the study area in 1976. A study was begun that year, the main objective of which was to relate decreases in foliar biomass to growth changes in spaced and unspaced stands (Piene 1989).

Eight 0.025-ha plots were established within 400 m of each other on similar forest sites, with four in a spaced stand and four in an adjacent unspaced stand (Piene et al. 1981). Two spaced and two unspaced plots were sprayed from the ground each year from 1977 to 1984 to protect them from spruce budworm defoliation. These spraying operations proved very successful and usually less than 10% of the current foliage was defoliated each year (Piene 1989).

### Defoliation Measurement

Defoliation was estimated on a subset of trees in each plot each year throughout the spruce budworm outbreak from 1976 to 1984. The same trees were sampled each year. For each tree, defoliation was estimated on one branch per whorl, starting from the top of the tree and moving to the base of the crown, with the same branches sampled each year. Within each sample branch, the second-order branches were used as discrete sampling units.

For each age class of foliage, all the shoots were individually assessed in eight defoliation classes: 0–10, 11–20, 21–40, 41–60, 61–80, 81–100, and 100%. An additional class included shoots that had had their terminal buds destroyed. Average percent defoliation by age class was calculated for each branch on the basis of the midpoint of each defoliation class. Visual assessment of defoliation on individual balsam fir shoots has proven to be an accurate method (MacLean and Morgan 1981).

### Foliar Analysis

Current foliage was collected after the growing season, from 1981 through 1984, from 10 trees outside the boundary of the two spaced and unspaced defoliated plots. About 60 to 80 current shoots were collected from south-facing branches from the upper to middle crown. In the laboratory, the needles were separated from the shoot axils and analyzed for their percent concentrations of N, P, K, Ca and Mg by the methods of MacDonald (1977).

### Population Levels

Ten trees outside each of one spaced and one unspaced defoliated plot, as well as one spaced and one unspaced protected plot, were sampled to determine spruce budworm population levels. Populations were sampled from 1977 to 1984 in the spaced defoliated plot, from 1978 to 1984 in the unspaced defoliated plot, and from 1978 to 1984 in the protected spaced and unspaced plots (Piene 1989).

One mid-crown branch was collected from each tree and the number of sixth-instar larvae and the total number of current shoots were counted for each 45-cm branch tip. Egg masses and second-instar larvae were counted from branches of three trees in the immediate vicinity of the study plots from 1976 to 1984. An exception was 1979, when only the number of egg masses was determined. Second-instar larvae and egg masses were counted according to the methods of Morris (1954) and Miller et al. (1971).

## RESULTS AND DISCUSSION

### Foliar Consumption Rates

Average percentage defoliation was correlated with the average number of sixth-instar larvae per shoot ($r = 0.97$), whereas no correlation existed between percentage defoliation and the number of egg masses ($r = 0.56$) or the number of second-instar larvae ($r = 0.58$). Based on the relationship between percentage defoliation and the number of sixth-instar larvae per shoot, 0.27 larvae per shoot will result in 100% defoliation of the current-year foliage; that is, one sixth-instar larva will consume about 3.7 balsam fir shoots. From data on the average weight of needles per shoot, based on shoots sampled from throughout the crown on sample trees in both spaced and unspaced defoliated plots from 1979 to 1984, one sixth-instar larva will consume and waste about 400 mg of needles. This compares with laboratory feeding rates of 125 to 254 mg (Miller 1977) and 207 to 315 mg (Thomas 1983) of balsam fir needles per sixth-instar larva. Since about 87% of the total budworm feeding occurs during the sixth instar (Miller 1977), these rates underestimate the total foliar consumption somewhat. Because these laboratory experiments also did not include the destroyed needle remnants that were not consumed by the spruce budworm, lower average rates would be expected. A comparison of the average value from the feeding experiments (225 mg), with that of the present study (400 mg), shows that the actual amount of damage resulting from direct feeding is about 55% of the total needle biomass removed by the spruce budworm.

## Defoliation in Spaced and Unspaced Stands

Percent defoliation was significantly higher for the spaced than for the unspaced trees in 1977, 1978 and 1980 (Table 1). In these years, the current foliage was destroyed early in the shoot elongation period and back-feeding, which was particularly severe in 1977 and 1978, occurred on older age classes of needles. Specifically, this difference was significant for 2-, 3-, and 4-year-old foliage in 1977, for 4-, 5-, and 6-year-old foliage in 1978, and for 1-year-old foliage in 1980 (Table 1). As a result, by the end of the outbreak in 1984, average spruce budworm-caused mortality was 44% in the spaced stands, and 19% (trees ≥ 6 cm DBH) in the unspaced stands (Piene 1989). This mortality was caused by defoliation only, since no mortality was noted in the spaced, protected plots and 94% of the dead trees in the unspaced protected plots were ≤ 6 cm DBH (Piene 1989).

These results suggest that there is no significant difference in defoliation between spaced and unspaced stands as long as only the current foliage is consumed. This represents levels of sixth-instar larvae of roughly 30 and 15 per branch tip for spaced and unspaced trees, respectively. These numbers represent the average number of larvae per 45-cm branch tip in 1979 and 1980.

The reason for the higher percent defoliation in the spaced stands in 1977, 1978 and 1980 is unclear. Open, exposed crowns, such as those in the spaced stands, provide preferred oviposition sites for spruce budworm moths and this may result in increased egg populations (Morris and Mott 1963) and hence increased budworm populations. This explanation seems unlikely since there was no significant difference in population levels between spaced and unspaced trees (except in 1979; see Table 2) throughout the outbreak.

Table 1. Average annual defoliation from 1976 to 1984, by age-class of foliage, for the sample trees in the spaced and unspaced plots in the Cape Breton Highlands, Nova Scotia (from Piene [1989]).

|  | Foliage age class[b] | Defoliation (%)[a] |  |  |  |
|---|---|---|---|---|---|
|  |  | Spaced trees |  | Unspaced trees |  |
|  |  | N | Mean ± SE | N | Mean ± SE |
| 1976 | C | 18 | 84.2 ± 6.7 | 18 | 85.3 ± 8.4 |
| 1977 | C | 15 | 100.0 ± 0.0 | 12 | 100.0 ± 0.0 |
|  | 1 | 15 | 13.4 ± 5.5 | 12 | 13.2 ± 9.1 |
|  | 2 | 15 | 71.5 ± 6.0[*] | 12 | 59.4 ± 10.9[*] |
|  | 3 | 15 | 51.3 ± 7.2[*] | 12 | 40.1 ± 8.2[*] |
|  | 4 | 15 | 37.1 ± 8.9[*] | 12 | 22.5 ± 7.1[*] |
|  | 5 | 15 | 29.5 ± 11.5 | 12 | 19.3 ± 5.9 |
|  | C-5 | 15 | 302.8 ± 30.9[*] | 12 | 254.5 ± 29.5 |
| 1978 | C | 15 | 100.0 ± 0.0 | 12 | 100.0 ± 0.0 |
|  | 2 | 15 | 1.9 ± 1.8 | 12 | 1.2 ± 1.4 |
|  | 3 | 15 | 19.1 ± 4.0 | 12 | 17.4 ± 4.9 |
|  | 4 | 15 | 33.3 ± 6.6[*] | 12 | 24.4 ± 4.6[*] |
|  | 5 | 15 | 36.7 ± 7.3[*] | 12 | 23.5 ± 7.5[*] |
|  | 6 | 15 | 33.0 ± 7.5[*] | 12 | 19.8 ± 8.2[*] |
|  | C-6 | 15 | 224.0 ± 21.0[*] | 12 | 186.3 ± 17.2[*] |
| 1979 | C | 27 | 76.0 ± 5.2 | 28 | 82.3 ± 4.8 |
| 1980 | C | 27 | 96.9 ± 1.7 | 28 | 95.6 ± 1.9 |
|  | 1 | 27 | 18.2 ± 4.7[*] | 28 | 12.1 ± 4.0[*] |
|  | C-1 | 27 | 115.1 ± 5.4[*] | 28 | 107.7 ± 4.0[*] |
| 1981 | C | 31 | 76.5 ± 6.5 | 38 | 71.2 ± 4.1 |
| 1982 | C | 24 | 39.0 ± 12.6 | 34 | 46.5 ± 8.4 |
| 1983 | C | 16 | 24.4 ± 12.6 | 28 | 34.1 ± 9.0 |
| 1984 | C | 14 | 12.6 ± 3.8 | 25 | 12.2 ± 3.0 |

Note: No defoliation estimate was done for 1-year-old foliage in 1978 because this age class was completely defoliated in 1977. The low defoliation for 2-year-old foliage in 1978 for the spaced and unspaced trees resulted from an almost complete defoliation of this age-class before 1978.

[a] Since there was no significant difference in percent defoliation between plots within the spaced and unspaced stands, trees were pooled in this analysis. N, number of sample trees; SE, standard error X t-statistic ($p = 0.05$).

[b] C, current foliage; 1, 2 etc., 1-, 2-year-old foliage, etc.; C-6, C-5, C-1, summed defoliation for each age-class starting with current and including 6-, 5-, and 1-year-old foliage, respectively.

[*] Significant difference in defoliation between spaced and unspaced trees ($p = 0.05$).

## Defoliation Surveys

Since about 1985, a number of forest companies in eastern Canada have conducted annual defoliation surveys in silviculturally treated stands. These are ground-based surveys in which individual forest stands are visited and percent defoliation is assessed from mid-crown branches, by age class, in areas representing average defoliation conditions. If possible, such surveys should be done annually, at least in areas where budworm defoliation is suspected. These defoliation surveys

Table 2. Average number of sixth-instar larvae per shoot and per 45-cm branch tip on one each of defoliated and protected, spaced and unspaced plots from 1977 to 1984 in the Cape Breton Highlands, Nova Scotia (from Piene [1989]).

| | | Defoliated plots | | | | Protected plots | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Spaced | | Unspaced | | Spaced | | Unspaced | |
| | N | Larvae per shoot | Larvae per 45-cm branch tip | Larvae per shoot | Larvae per 45-cm branch tip | Larvae per shoot | Larvae per 45-cm branch tip | Larvae per shoot | Larvae per 45-cm branch tip |
| 1977 | 10 | 1.18 | 71 | – | – | – | – | – | – |
| 1978 | 10 | 0.78 | 68 | 0.73 | 48 | 0.01 | 1 | 0.01 | 1 |
| 1979 | 10 | 0.27* | 25 | 0.15* | 11 | 0.01 | 1 | 0.01 | 2 |
| 1980 | 10 | 0.19 | 35 | 0.17 | 20 | 0 | 0 | 0.02 | 1 |
| 1981 | 10 | 0.09 | 3 | 0.07 | 4 | 0 | 0 | 0 | 0 |
| 1982 | 10 | 0.01 | 1 | 0.04 | 6 | 0 | 0 | 0 | 0 |
| 1983 | 10 | 0 | 0 | 0.02 | 2 | 0 | 0 | 0 | 0 |
| 1984 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note: N, number of sample trees; –, no data.
* significant difference in the number of larvae per shoot between spaced and unspaced trees ($p = 0.05$).

have proven to be inexpensive and could easily be modified and combined with aerial survey techniques. The surveys serve two main purposes: (1) they aid in protection planning to prevent severe defoliation, which is particularly important for species such as balsam fir that are extremely sensitive to defoliation (Piene 1980); and (2) they help in the development of defoliation histories for individual stands, which allow adjustments of future stand-yield predictions.

## CONCLUSIONS

Defoliation is not increased in spaced balsam fir stands defoliated by the spruce budworm as long as only the current foliage is consumed. (Up to about 30 and 15 sixth-instar larvae per 45 cm branch tip for spaced and unspaced stands, respectively.) Significantly higher defoliation was observed in spaced stands during years of extreme budworm population levels, and was characterized by a destruction of the current foliage combined with severe backfeeding on older age classes. As a consequence, budworm-caused mortality averaged 44% in the spaced stands and 19% in the unspaced stands.

## LITERATURE CITED

Alfaro, R.I. and Omule, S.A.Y. 1990. The effects of spacing on Sitka spruce weevil damage to Sitka spruce. Can. J. For. Res. 20:179–184.

Batzer, H.O. 1967. Spruce budworm defoliation is reduced most by commercial clearcutting. USDA For. Serv., North Central For. Exp. Stn., St. Paul, Minn. Res. Note NC-36.

Bella, I.E. 1985. Pest damage incidence in natural and thinned lodgepole pine in Alberta. For. Chron. 61:233–238.

Blais, J.R. 1958. The vulnerability of balsam fir to spruce budworm attack in northwestern Ontario, with special reference to the physiological age of the tree. For. Chron. 34:405–422.

Blum, B.M. and MacLean, D.A. 1985. Potential silviculture, harvesting and salvage practices in eastern North America. p. 264-280 *in* C.J. Sanders, R.W. Stark, E.J. Mullins and J. Murphy, *Ed.* Recent Advances in spruce budworms research. Proc. CANUSA Spruce Budworms Res. Symp., Bangor, Maine. Dep. Environ., Can. For. Serv., Ottawa, Ont. 527 p.

Craighead, F.C. 1925. Relation between mortality of trees attacked by the spruce budworm (*Cacoecia fumiferana* Clem.) and previous growth. J. Agric. Res. 30:541–555.

Crook, G.W., Vézina, P.E. and Hardy, Y. 1979. Susceptibility of balsam fir to spruce budworm defoliation as affected by thinning. Can. J. For. Res. 9:428–435.

Fauss, D.L. and Pierce, W.R. 1969. Stand conditions and spruce budworm damage in a western Montana forest. J. For. 67:322–325.

Forbes, R.S., Underwood, G.R. and Van Sickle, G.A. 1975. Forest pest conditions in the Maritimes in 1974 with an outlook for 1975. Dep. Environ., Can. For. Serv., Fredericton, N.B. Inf. Rep. M–X–53.

Kleinschmidt, S.M., Baskerville, G.L. and Solomon, D.S. 1980. Reduction of volume increment in fir-spruce stands due to defoliation by spruce budworm. Univ. New Brunswick, Fac. For., Fredericton, N.B.

MacDonald, C.C. 1977. Method of soil and tissue analysis used in the analytical laboratory. Dep. Environ., Can. For. Serv., Fredericton, N.B. Inf. Rep. M–X–78.

MacLean, D.A. 1980. Vulnerability of fir-spruce stands during uncontrolled spruce budworm outbreaks: a review and discussion. For. Chron. 56:213–221.

MacLean, D.A. and Morgan, M.G. 1981. The use of phyllotaxis in estimating defoliation of individual balsam fir shoots. Dep. Environ., Can. For. Serv., Ottawa, Ont. Bi-monthly Res. Notes 1:12–14.

Miller, C.A. 1977. The feeding impact of spruce budworm on balsam fir. Can. J. For. Res. 7:76–84.

Miller, C.A., Kettela, E.G. and McDougall, G.A. 1971. A sampling technique for overwintering spruce budworm and its applicability to population surveys. Dep. Environ., Can. For. Serv., Fredericton, N.B. Inf. Rep. M–X–25.

Mitchell, R.G., Waring, R.H. and Pitman, G.B. 1983. Thinning lodgepole pine increases tree vigor and resistance to mountain pine beetle. For. Sci. 29:204–211.

Morris, R.F. 1954. A sequential sampling technique for spruce budworm egg surveys. Can. J. Zool. 32:302–313.

Morris, R.F. and Mott, D.G. 1963. Dispersal and the spruce budworm. p. 180-189 *in* R.F. Morris, *Ed.* The dynamics of epidemic spruce budworm populations. Mem. Ent. Soc. Can. No. 31.

Piene, H. 1980. Effects of insect defoliation on growth and foliar nutrients of young balsam fir. For. Sci. 26:665–673.

Piene, H. 1989. Spruce budworm defoliation and growth loss in young balsam fir: defoliation in spaced and unspaced stands and individual tree survival. Can. J. For. Res. 19:1211–1217.

Piene, H., MacLean, D.A. and Wall, R.E. 1981. Effects of spruce budworm-caused defoliation on the growth of balsam fir: experimental design and methodology. Dep. Environ., Can. For. Serv., Fredericton, N.B. Inf. Rep. M–X–128.

Thomas, A.W. 1983. Foliage consumption by 6th-instar spruce budworm larvae, *Choristoneura fumiferana* (Clem.), feeding on balsam fir and white spruce. p. 47-48 *in* R.L. Talerico and M. Montgomery, *Tech. Coord.* Forest defoliator – host interactions: a comparison between gypsy moth and spruce budworms. USDA For. Serv., Northeastern For. Exp. Stn., Newhaven, Conn. Gen. Tech. Rep. NE–85.

# PATHOLOGICAL CONSIDERATIONS FOR STAND TENDING IN ONTARIO

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## ABSTRACT

Spacing and practices that change spacing are discussed with respect to diseases of the boreal forest. Management practices and the impact of associated mechanical activities are described from a pathological viewpoint. The implications of spacing and potential problems resulting from spacing projects are discussed.

## RÉSUMÉ

On examine l'espacement et les méthodes de gestion qui influent sur ce facteur en relation avec les maladies de la forêt boréale. On décrit, au point de vue de la phytopathologie, des méthodes de gestion et les effets des activités mécaniques qui s'associent. On traite également des conséquences de l'espacement et des problèmes pouvant résulter des opérations d'espacement.

## INTRODUCTION

The pathogenic role of pests in the forest community needs to be considered as part of a more complex system that considers the host as well as environmental interactions. Pathologists refer to the pathogen/host/environment complex as the disease triangle, and try to understand and control diseases by studying and manipulating the three components of the triangle. The way that the disease projects itself between phases in the forest or generations of the pathogen is known as the disease cycle. Consideration of the environment includes provision for the influence of human activities as well as pests such as insects that can effect a pathogen's success.

Stand-tending practices that improve the space allocation for trees influence the host as well as the environment. Tree vigor usually improves after a short period of adjustment. Boyce (1961) noted that "There is no factor more important in relation to disease than tree vigor." Sound forestry provides for healthy forests. The "Integrated Pest Management" concept, which combines pest management with forest management, must be ingrained in our planning process.

Recently, I heard a presentation by R. Day[1], who stressed the need for a crop plan for every stand or group of similar stands. The plan's principal function is to maintain optimal production throughout a forecast rotation. The plan starts with a pre-cut inspection and includes a prescription for harvesting method, slash disposal, site preparation, regeneration, stand tending, thinning and intermediate cuts, etc. I like the idea of individualized stand plans especially if disease, insect and vegetation management is part of the plan. The silvicultural guidelines for red pine (*Pinus resinosa* Ait.) and white pine (*P. strobus* L.) (Chapeskie et al. 1989) and spruce (*Picea* spp.) (Arnup et al. 1988) include pest-management information. A more detailed set of guidelines for white pine blister rust (*Cronartium ribicola* J.C. Fischer) and white pine weevil (*Pissodes strobi* Peck) management (Hodge et al. 1989) was produced by a joint effort between pest specialists and management foresters. This kind of cooperative effort is a very good approach to developing the kind of guidelines and other suitable information needed for stand and crop planning.

### Pathogens

Organisms that cause disease are called pathogens. This term is usually reserved for biotic causes such as fungi, nematodes, bacteria, viruses and mycoplasmas. Abiotic causes of disease, such as pollution, are a distinct group of problems. Pathogens require an energy source such as an infected tree to continue to exist. Pathogens commonly have the capability to infect and kill all or a portion of the host and then exist on the diseased material, using it as their energy source. Some of the energy is used to produce the inoculum that infects other individuals. Inoculum, usually in the form of small spores or other infectious material, is present in large numbers, giving pathogens a tremendous capability to multiply or spread when favorable environmental conditions exist. Managing the forest in a manner that reduces the inoculum's potential to spread is an important concept in disease control.

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[1] Day, R.J. Crop planning for white pine plantation management. Paper presented at the managing and marketing white pine plantations workshop. April 1990. Kingston, Ont. Unpubl. Rep.

### Host

The character of the host is part of the disease triangle. Genetic resistance is outside the scope of this meeting, but it is an obvious character to illustrate the importance of the host's role. Increased host vigor results from reduced competition for the life-support systems that comprise the environmental part of the triangle. Vigorous trees can often prevent penetration by a pathogen or can wall-off infected parts to prevent intensification of the infection. Host vigor is also a survival mechanism against diseases such as Scleroderris canker (*Ascocalyx abientina* [Lagerb.] Schläpfer-Bernhard), in which the infection hazard is confined to a specific zone. For Scleroderris canker, infection rarely occurs beyond 2 m above the ground. Vigorous trees reach the size necessary to survive such infections faster than less vigorous trees.

### Environment

Site quality affects vigor. As well, pathogens require favorable environmental conditions for infection, growth and replication. The amount of infection that occurs varies widely over time for most diseases. Weather and other environmental conditions usually influence this variability. As an example, infection commonly requires moist conditions for an extended period of time. Stand-tending operations change the environment for both the host and pathogen. Light, temperature, humidity, air movement, water and nutrient supply can be affected, and each can affect the host and the ability of the pathogen to affect the host.

## DISEASE-CONTROL TECHNIQUES

This paper presents disease management as part of the stand-planning process. Disease-control concepts that can be incorporated into stand-tending plans are discussed, as are disease problems that could affect the success of such practices.

Sanitation cutting throughout an area eliminates sufficient material containing the pathogen to protect the stands of interest. Roguing of diseased individuals and pathological pruning are forms of sanitation. Often a combination of these two practices provides acceptable control of a disease. Pathological pruning involves removing infected branches and those likely to become infected. Frequently, branches in a zone just above ground level are especially susceptible to infection. Scleroderris canker and the white pine blister rust seem to respond well to this kind of control (Dorworth 1976, Hodge et al. 1989).

Discriminating against diseased trees during stand-tending practices can provide at least partial sanitation. Diseased trees tend to grow more slowly and have reduced quality compared with unaffected individuals and, hence, are logical choices for removal. These trees can constitute a contagion hazard to the trees that are reserved for future harvest. When removal of diseased trees would reduce stocking below acceptable levels, it would be better to consult a pest-control specialist. The magnitude of the pest problem could be serious and require special precautions.

Matching tree species to sites and improving tree vigor are good silvicultural concepts, and are also good for pathogen control. However, many of the disease situations that have been observed over the years resulted from mismatches of species and site or merely attempts to grow trees on adverse sites. Good silviculture circumvents pathological problems. The development of trees with improved pest resistance is one of the more promising strategies in pest control today; however, the host-site interaction is equally important with improved trees.

Pesticides can be effective against certain foliar diseases, and protection of ornamental trees and nursery crops is often warranted. Application of pesticides to forest situations is costly, and most chemicals act only to prevent rather than control infection. In Ontario we have not experienced foliar disease problems that would warrant costly control programs.

Annosus root rot (*Heterobasidion annosum* (Fr.) Bref.) has caused considerable damage to red pine in southern Ontario. The fungus commonly infects surfaces of cut stumps and logging wounds. Treatment of such surfaces with borax or sodium nitrite has been prescribed (Myren and Punter 1972) after harvesting pine in southern Ontario. Such action could prevent establishment of the fungus in plantations or on sites to be regenerated with pine.

Red pine thinnings in northern Ontario do not seem to experience damage from Annosus root rot. Nonetheless, Annosus root rot should be considered a potential problem in the management of all conifers and one should watch for symptoms of this disease after thinning operations. Infection of logging wounds and stumps has been reported for Norway spruce (*Picea abies* [L.] Karst.) stands in Scandinavia (Isomäki and Kallio 1974) and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in western North America (Hunt and Krueger 1962).

## Release Treatments

Competition control by weeding and cleaning is often necessary to release favored species that are growing with or under less-favored species. Herbicides are often used to release coniferous species from deciduous competition. Situations have occurred in which root rots that were present on the root systems of killed deciduous vegetation have invaded, colonized and killed the coniferous trees that were to be released. Aspen sucker stands that have root systems linked with a network of parent roots present a hazard in the use of this kind of competition treatment to release conifers. Basham (1988) described the character of these root systems, which sustained a high proportion of infection by *Armillaria* spp. (mostly *Armillaria obscura* [Pers.] Herink), the cause of Armillaria root rot. Herbicide release is usually a satisfactory means of controlling competition from aspen suckers. One can, however, expect situations in which the occurrence of root rot on competing species such as aspen can become a problem for the released species.

## Sanitation and Early Pruning

Sanitation and pruning have disease-control value. Often, they prevent complete plantation failure. One achieves a much better selection base of potential crop trees by treating early to reduce the impact of pests on the host trees. As well, for diseases such as Scleroderris canker, treatment preserves the option of planting nearby sites that would otherwise be unplantable because of the high infection hazard from the inoculum being produced in the affected stand.

Sanitation and pathological pruning treatments are most effective when started early in the life of a stand. Management plans need to include a provision for these inspections and treatments if they are prescribed.

Scleroderris canker of red pine and white pine blister rust are two problems that can be controlled effectively by sanitation and pruning. Guidelines for controlling blister rust are provided by Hodge et al. (1989), and those for Scleroderris canker are provided by Dorworth (1976). Both diseases infect needles or shoots in the lower part of the crown of young trees. The first few whorls of branches near the ground are highly susceptible to infection, probably because foliage there is more compact and dense than that in the upper whorls. Infection by the North American race of Sclerroderris rarely occurs more than 2 m above ground (Gross and Dorworth 1978). Although infection by the more aggressive European race is not confined to the lower crown, it does seem to occur mostly in the lower 2 m of the tree. Pruning the branches in a series of treatments to provide 2 m of clear stem eliminates the most susceptible sites for infection and, in the process, many infections are severed from the tree before the infection reaches the bole and causes a canker.

Control of Scleroderris canker requires a series of inspections at intervals of 2-3 years. At the first inspection the red pines are too small for pruning entire whorls, but infected trees should be removed. Pruning infected shoots seems inadvisable because, at this small size, most infections will have reached the main stem. Pruning the first two or three whorls of branches as soon as possible provides early control when the trees are small and easily killed. Additional pruning can be scheduled depending on the amount of infection detected during the inspections. The final sanitation pruning can probably be combined with a precommercial thinning, as trees would be about 4 m in height by then and crown closure will have occurred for most planting densities currently described. Suppressed trees of low vigor seem especially susceptible to Scleroderris canker, and because of their size it can be difficult to remove many low branches without further affecting vigor. I recommend removal of these trees, regardless of infection status. Removal of diseased trees probably does not result in a root-rot hazard associated with the stumps. Infected branches and trees continue to produce inoculum for Scleroderris canker after pruning or felling, but the period of production is short and the expense of removing them seems unnecessary unless the intensity of infection is high.

## Precommercial Thinning

It is beneficial for most commercial tree species to experience competition early during stand development to achieve the desired tree form and quality. The optimal tree density required to achieve maximum crop harvest is lower than that required to get the desired form and quality. Day (1990) (see footnote 1) notes that tolerant hardwoods and branchy conifers are examples of species that need to be "trained" and will thus need precommercial thinning. Disease management needs to be a part of this prescription. Thinning presents an opportunity to sanitize the stand.

Thinning crews must to be able to identify disease symptoms; otherwise, more experienced personnel are needed to mark the diseased trees for removal. Most canker diseases are distinct and easily recognized. However, I have observed several precommercial thinnings of jack pine that did not seem to reduce the amount of gall rust (*Endocronartium harknessii* [J.P. Moore] Y. Hirats.) or stem cankers caused by several rusts (*Cronartium* spp.). Guilkey et al. (1958) observed a similar situation in Michigan. I am sure pathologists can identify these diseases more easily than thinning crews, but I also feel that crews can be trained to an adequate level of competence.

Precommercial thinning requires early selection of crop trees. Some pests such as white pine weevil show an early preference for large trees. Root rots and other pests could also cause mortality in the future. Hence, it is wise to provide a buffer of extra crop trees to ensure an acceptable density for future selections.

Root rots may not be as much of a problem for precommercial thinnings as for commercial thinning. For precommercial trees, the number of root contacts is lower and the severed root systems are smaller than in stands of commercial-sized trees. Armillaria root rot seems to be the most important disease of young stands (Whitney 1988a). Unpublished data from Forestry Canada's Forest Insect and Disease Survey and Whitney's (1988a) data seem to indicate that the usual amount of mortality caused by root rot in our young coniferous stands is low. However, serious losses (> 10% mortality) have occurred under certain circumstances (ibid.).

As described previously, stumps resulting from precommercial thinning of pine in southern Ontario must be treated to prevent Annosus root rot. Similarly, it seems advisable to monitor all thinning operations in conifers for the presence of this disease.

Thinning in stands that exhibit much mortality caused by root rot is not advised. The hazard of additional rot-induced mortality is too great to justify the investment: either solve the root rot problem or wait until mortality is reduced to acceptable levels before investing in a precommercial treatment. Sometimes, root rot activity in juvenile stands declines after stumps and other energy sources that support the pathogen deteriorate.

Basham's (1988) investigation of the growth of young aspen suckers showed that considerable root rot was carried over to the suckers from the parent root systems. Surprisingly, there was not much evidence of mortality or growth loss; nonetheless, I advise caution in approaching aspen thinning projects.

Stem decay should not be much of a problem after precommercial thinning. Tree size is smaller and cut trees are usually not removed. Thus, the size and number of felling injuries is reduced and mechanical injuries do not occur.

## Commercial Thinning

Commercial thinnings can cause wounds to the crown, stem and roots of the residual crop trees. The trees need to be extracted and, if used, heavy equipment tends to compact the ground along the main skid roads. Damage varies with the kind of equipment used and the attitude and skill of the operators. Other speakers will undoubtedly address these topics. The need for a harvesting plan and adherence to the plan must be emphasized, as there are pathological implications. Wounds are potential infection courts for organisms that can cause stem decay, root rot and cankers. Conscientious felling and skidding keeps such wounding to a minimum. A few strategically placed trees acting as fenders along skid roads can prevent considerable damage, and these can be harvested as part of a final cleanup.

The importance of logging injuries after an improvement cut in white pine was studied by Whitney and Brace (1979). About 20% of the trees were wounded, and wood decay had affected the merchantable part of about 30% of these trees 5 years after logging. The size and location of the wounds seemed important. Basal wounds and those that were gouged or that extended into the woody stem were more commonly affected and more extensively decayed. Other studies of logging damage in operations in Norway spruce, western hemlock and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) (Isomäki and Kallio 1974, Hunt and Krueger 1962) reported similar results. Isomäki and Kallio reported reduced height and diameter growth in proportion to the size of the injury. Some amount of logging damage seems inescapable, but the above studies illustrate the importance of minimizing this damage.

Wood near wounds becomes what some call pathologic heartwood, and most of the common decay fungi can infect these sites. Many kinds of decay are compartmentalized in the classic manner described by Shigo (1979). Other infections tend to be mavericks that can cause extensive decay. One way to improve the quality of the residual crop trees is to thin in two stages, harvesting the damaged trees and reducing density to the preferred level as part of a second cut. This also has merit for preventing excessive losses to root rots.

Sanitation cutting for disease control should be considered part of improvement cuts. The discussion presented for precommercial thinnings applies also to commercial cuts. When the trees to be cut are marked, sanitation harvesting can be much more effective, as diseased individuals are more likely to be cut.

With the exception of red pine, we have not had much experience with thinnings in Ontario. The precautions and treatment described previously for the prevention of Annosus root rot apply equally well to commercial cuts.

Whitney (1983, 1988a, 1988b) has presented considerable data indicating that a high potential exists for root rot problems in our spruce and fir (*Abies* spp.) stands. Annosus root rot has caused considerable damage to red pine in southern Ontario, and treatment of stumps with borax or sodium nitrite is prescribed for all thinnings (Myren and Punter 1972). This stops entrance of the fungus into a stand but does not stop its spread through the root systems. Red pine thinnings in northern Ontario do not seem to sustain damage from Annosus root rot.

Root rots represent probably the most perplexing problem in stand-tending operations. Affected individuals are often difficult to identify. Many tree species form an interconnected network of roots that can facilitate movement of infection from one root system to another. Stumps and root systems of cut trees provide a food base for the pathogen that then supports movement to other trees. Affected trees often die from root loss. Roots also provide support. Trees with extensive root rot are prone to windthrow.

Thinning provides a massive amount of susceptible roots that the fungus can use as an energy base to support their penetration of the roots of residual trees. Thinning also removes trees that were providing wind protection, and many trees affected by root rot can be blown over. This has not been a serious problem in Ontario, but then we have not had much thinning experience. The phenomenon has been experienced in the West in stands affected by the yellow laminated root rot (*Phellinus weirii* [Murr.] Gilbn.). There, Douglas-fir, the preferred species, is more prone to the root rot than is western hemlock. As such, forest managers have either curtailed partial cutting in affected stands or have applied a two-stage cutting system that allows the stand to undergo mortality before it is cut again to attain the preferred density. Laminated root rot is a very significant problem in managing coastal conifers. Whitney (1983) described the impact of root rot after thinning in plantations of spruce (*Picea* spp.) in Ontario. Significant growth loss and mortality occurred. In this instance, root rot was a major problem after thinning.

## SUMMARY

In summary, there are ways to achieve disease control through stand-tending practices. There are also disease problems that can be stimulated by thinning. Foresters should consider disease-control possibilities and the consequences of disease as part of each stand plan. We can expect our knowledge and capability of combating diseases to improve as stand-tending operations become more common. Overall, stand vigor can be expected to improve and we will be able to provide better disease control for our forest.

## LITERATURE CITED

Arnup, R.W., Campbell, B.A., Raper, R.P., Squires, M.F., Virgo, K.D., Wearn, V.H. and White, R.G. 1988. A silvicultural guide for the spruce working group in Ontario. Ont. Min. Nat. Resour., Toronto, Ont. Sci. Technol. Ser., Vol. 4. 100 p.

Basham, J.T. 1988. Decay and stain 10 years later in aspen suckers subjected to scarification at age 3. Can. J. For. Res. 18:1507–1521.

Boyce, J.S. 1961. Forest pathology. 3rd ed. McGraw-Hill, Toronto, Ont. 572 p.

Chapeskie, D.J., Galley, P.F., Mihell, J.R., Quinn, N.W. and Struik, H.H. 1989. A silvicultural guide for the white pine and red pine working groups in Ontario. Ont. Min. Nat. Resour., Toronto, Ont. Sci. and Technol. Ser., Vol. 6. 102 p.

Dorworth, C.C. 1976. Reducing damage to red pine by *Gremmeniella abietina* in the Great Lakes-St. Lawrence forest region of Ontario. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Rep. O–X–252. 22 p.

Gross, H.L. and Dorworth, C.E. 1978. *Gremmeniella* (*Scleroderris*) disease of conifers. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Leafl. 8 p.

Guilkey, P.C., Rudolph, V.V. and Sheppard, G. 1958. Effects of sweetfern rust on the growth of young jack pine in northern lower Michigan. J. For. 56:900–903.

Hodge, J.C., Gross, H.L. and Retnakaran, A. 1989. White pine blister rust and white pine weevil management guidelines for white pine in Ontario. Ont. Min. Nat. Resour., Pest Mgt. Sect., Toronto, Ont. Rep. PM–36. 21 p.

Hunt, J. and Krueger, W.K. 1962. Decay associated with thinning wounds in young growth western hemlock and Douglas-fir. J. For. 60:336–340.

Isomäki, A. and Kallio, T. 1974. Consequences of injury caused by timber harvesting machines on the growth and decay of spruce (*Picea abies* [L.] Karst.). Acta For. Fenn. 136:3–25

Myren, D.T. and Punter, D. 1972. An evaluation of six methods for protecting pine stump tops from infection by *Fomes annosus* in Ontario. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Rep. O–X–164.

Shigo, A.L. 1979. Tree decay: an expanded concept. USDA For. Serv., Washington, D.C. Agric. Inf. Bull. No. 419. 73 p.

Whitney, R.D. 1983. Diseases of conifer plantations. p. 254–276 *in* Proc. Newfoundland Silviculture Symp., Grand Falls, Nfld. 5-6 April 1983. 326 p.

Whitney, R.D. 1988a. *Armillaria* root rot damage in softwood plantations in Ontario. For. Chron. 64:345–351.

Whitney, R.D. 1988b. Root rot damage in naturally regenerated stands of spruce and balsam fir in Ontario. Can. J. For. Res. 19:295–308.

Whitney, R.D. and Brace, L.G. 1979. Internal defect resulting from logging wounds in residual white pine trees. For. Chron. 55:8–12.

# WILDLIFE CONSIDERATIONS IN THINNING AND SPACING OF CANADIAN FORESTS

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## ABSTRACT

Thinning activities in forest stands affect wildlife if dense stands are opened or if hardwood trees and snags are removed. A majority of small mammals, furbearing animals and nesting birds prefer open forest, although some species select dense stands. Ungulate species benefit from the greater forage in open stands if security and thermal cover are also available. Conversely, browsing damage can be reduced by thinnings that limit cover.

## RÉSUMÉ

L'éclaircie des peuplements forestiers a une incidence sur la faune lorsqu'on dégage les forêts denses ou élimine les essences feuillus et les chandelles. Beaucoup de petits mammifères, d'animaux à fourrure et d'oiseaux nicheurs préfèrent la forêt ouverte, mais certaines espèces affectionnent les peuplements plus denses. Les ongulés tirent parti de l'abondance des fourrages dans les peuplements ouverts si ces derniers leur offrent également la sécurité et la protection thermique qu'ils recherchent. Parallèlement, on peut réduire les dommages causés par le broutage en procédant à des éclaircies qui diminueront la couverte arbustive.

## INTRODUCTION

The silvicultural treatments of thinning and spacing are attracting increasing attention as a means of relieving wood shortages (Brace and Golec 1982; Samoil 1990; M. Litchfield, this volume; F.L.C. Reed, this volume). Spacing changes the structure of the forest, thereby changing the conditions of life for wild mammals and birds, and is therefore important in wildlife management. Over the millennia, wildlife species have adapted to occupy habitat niches presented by the constantly changing forest system. As a result, groups of species have developed that use the resources of particular forest condition classes. One community of birds and mammals will use early successional shrub and sapling forests whereas another will occupy old-growth habitats and mid-aged stands (Perkins 1974, Crawford et al. 1981, Trottier et al. 1989).

The early successional stage of stand development after clearcutting or fire is characterized by a short but often dense and patchy growth of saplings and shrubs and by high production of forage used by big game animals. Many species of small mammals, furbearing animals and songbirds are also particularly adapted to the shrub stage of succession (Bunnell and Eastman 1976, Telfer 1976).

In naturally regenerating stands, tree seedlings will start growing earlier in some locations than in others, forming patches of mid-sized trees while intervening areas remain in the shrub stage. In lodgepole pine (*Pinus contorta* Dougl.) stands in Alberta, this stage is reached at about 20 years after cutting. The patches of mid-sized trees spread and coalesce until only scattered openings containing shrubs remain. In plantations, closing of the crown canopy happens more uniformly and thus more suddenly.

Dr. Jerry Franklin, a leading proponent of taking a fresh look at forest ecology and management, recently remarked that the closure of the crown cover of a young forest is the most traumatic occurrence in the history of the stand in terms of its impact on plants and animals (J. Franklin, Forest Industry lecture at the Forest Science Department, University of Alberta, 4 April 1990, unpublished).

After the tree canopy closes, the understory plant biomass decreases sharply and changes in composition (Pase and Hurd 1958, Telfer 1972, Crawford 1976). Although site factors and vegetational history are important in determining the nature and persistence of understory plants, the density of the crown canopy is the major controlling factor. With the decline of the understory comes a rapid decline in use of the stand by ungulates for foraging and by birds and small mammals dependent on shrub and herbaceous cover. There is also a shift to a higher proportion of birds that are more characteristic of older forests.

The purpose of this paper is to contrast the normal course of forest succession with conditions created by thinning and spacing activities. I will also comment on the use of thinning to improve wildlife habitat and the relation of thinning to forest damage by browsing mammals. The impacts of land management on wildlife occur at various scales. I will focus on the forest-stand level — the actual treatment site — and also on the landscape level, looking at the impact on larger landscapes of having thinned stands within them.

## STAND-LEVEL WILDLIFE CONSIDERATIONS

Thinning and spacing in forests have little impact on wildlife unless stand density is reduced from dense to open. For this analysis, I consider an "open" stand to have a crown cover of < 50% whereas "dense" stands have > 50% cover; 50% crown cover in coniferous forests corresponds roughly to 17 $m^2$/ha of basal area.

Most provincial forest inventories use a cover-type system that rates the stand-density class. For example, the Saskatchewan system uses the following classes: A = 10–30%, B = 30–55%, C = 55–80% and D = 80–100% crown closure. Thus, the A and B classes represent open stands and the C and D classes represent dense forest. Thinning and spacing would usually be aimed at stands in the D category, with the object of reducing density to that of the B category. Although wildlife habitat studies have not usually been reported in a manner that permits an easy fit with such forestry categories, it was possible to assign the habitat preferences of different species to the open or dense categories. The result of this review of habitat selection by wildlife species suggests that a majority make greater use of forest stands with open crown canopies than of those with dense canopies (Fig. 1).

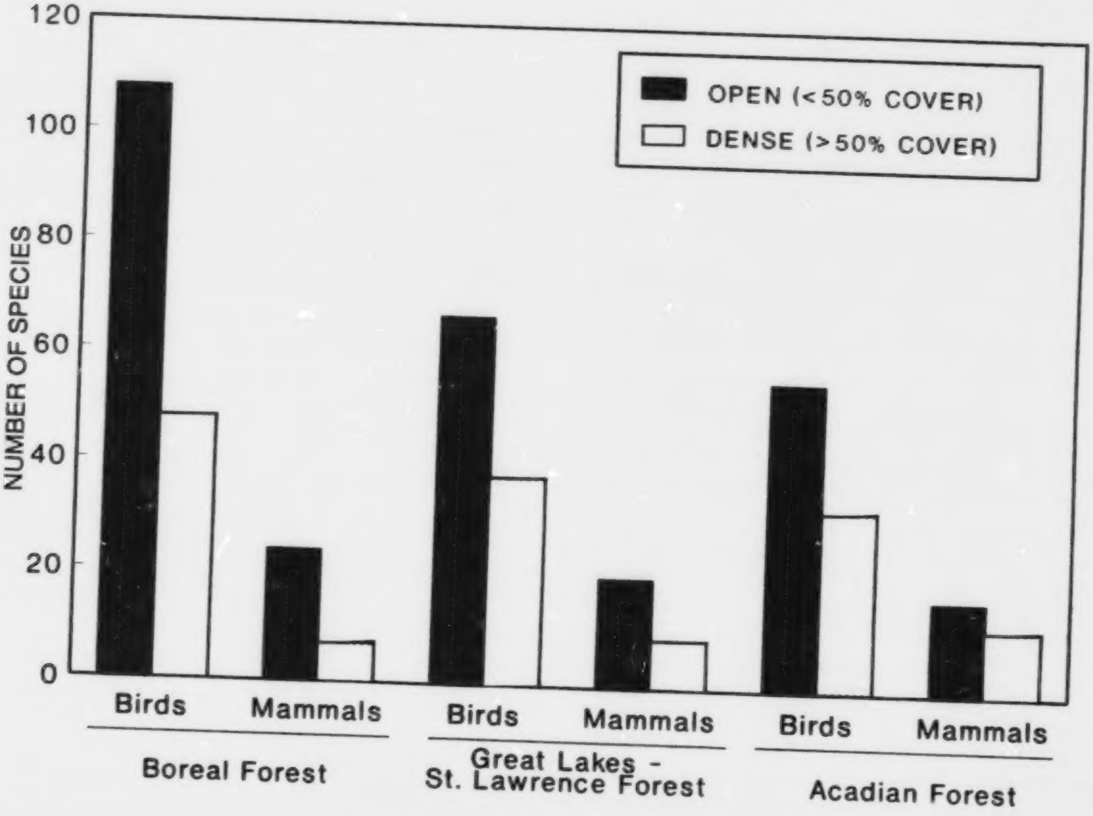


*Figure 1. Habitat selection by small mammals, furbearing animals and nesting birds in open and dense tree crown-cover classes in three Canadian forest regions. Based on a review of habitat selection described in standard references (Telfer 1976). (The large number of species in the Boreal Region results from the occurrence of species typical of the Pacific slope as well as those of eastern North America in this vast transcontinental region.)*

Most species exhibit considerable tolerance for a range of stand densities and many, especially the mammals, will move between stands of different densities depending on food availability and cover needs.

Density is, of course, only one characteristic of forest stands. Other characteristics such as species composition and tree size are also important considerations.

Habitat selection by large ungulates such as moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*) and caribou (*Rangifer tarandus*) is more complex. These species use dense forest as cover for calving, for a cooler or warmer thermal environment, and to avoid predators, including hunters. However, they also require the large amounts of forage produced by the understory in open stands.

In all thinning and spacing there is usually an aspect of weeding. If softwoods such as spruce (*Picea* spp.), jack pine (*Pinus banksiana* Lamb.), lodgepole pine and Douglas-fir (*Pseudotsuga menziesii* Franco) are the desired crop species, then the first stems removed will be competing hardwoods. This is particularly true of chemical weeding of sapling stands. Cover-type mapping in the Saskatchewan provincial inventory classifies cover types as follows: S = more than 75% softwood; SH = 50–75% softwood; HS = 25–50% softwood, 50–75% hardwood; H = more than 75% hardwood. The usual effect of thinning is to shift cover-type composition toward softwoods. Except where northern hardwoods are marketable, thinning and spacing are largely confined to S, SH and marginal HS stands. Thinning shifts these stands into the S class or, where there is a high proportion of hardwood, to marginally SH stands. Removal of hardwoods, if conducted in a rigorous manner, reduces nesting habitat for some bird species and, in the case of weeding in sapling stands, may also reduce ungulate forage.

In the western Canadian boreal forest, 33 species of birds nest in holes in dead or moribund trees. These include groups such as the woodpeckers, the chickadees, the bluebirds and some species of swallows, owls and ducks. Some mammals also use tree cavities when producing their young or for shelter from extreme cold; these include martens (*Marten americana*), flying squirrels (*Glaucomys sabrinus*), red squirrels (*Tamiasciurus hudsonicus*) and raccoons (*Procyon lotor*). The loss of dead trees, snags, and of the large cull trees that are future snags, is a serious problem in managed forests. Snags are sometimes dangerous to work around because of their rotten condition and must be felled as a safety measure in some provinces. Many are also felled from a misplaced sense of tidiness. In stands that originate after logging, snags may be already gone by the time stand tending begins. However, should snags be present, attempts should be made to spare a substantial number of them. One approach is to leave patches of snags and culls systematically spaced throughout the area. Such patches could be incorporated into areas left untreated for ungulate shelter, for travelways or for streamside reserves.

Ungulate habitat consists of three structural elements: open, forage-producing areas; areas with tree cover that is adequate for hiding and predator avoidance; and dense, usually older, forest stands that provide thermal cover, both against heat in summer and cold and snow in winter (Thomas 1979). Thinning can be very beneficial in providing additional forage for moose, deer and elk, and possibly for caribou, but can have a negative impact on the provision of places to hide and of thermal cover.

The magnitude of the production of additional forage that can result from thinning is shown in Figure 2. The yield of additional forage is estimated for a juvenile spacing at 19 years and for a later, possibly commercial, thinning. The impact of the thinning is to raise forage production toward that of early successional levels and to maintain a higher production of forage for a period of several years. Crouch (1986) reported elevated forage production up to 15 years after thinning in lodgepole pine stands in Colorado. Provided that adequate cover interspersed with thinned stands is available, the forage yield and the amount of ungulate use in a management unit can be substantially increased by thinning the softwood stands. Analysis of the economic value of the additional big game animals that could be supported by the extra forage made available under a thinning program in Manitoba and Saskatchewan would contribute substantially to the economic viability of such programs (W. Ondro, Forestry Canada, Edmonton, personal communication).

Caribou provide unique habitat-management problems. Much of the range of caribou in Canada lies beyond the commercial forest zone. However, open spruce and jack pine forests were found to have the greatest biomass of lichens in a Manitoba study (Miller 1976), and caribou habitat-management guidelines for Idaho recommend stands of medium density for all seasons except early winter (Zack 1987). This suggests that thinning and other forms of partial cutting may be compatible with the production of winter forage for caribou.

## LANDSCAPE-LEVEL WILDLIFE CONSIDERATIONS

Thinned forest stands change the value to wildlife of the larger land units within which they occur. This is

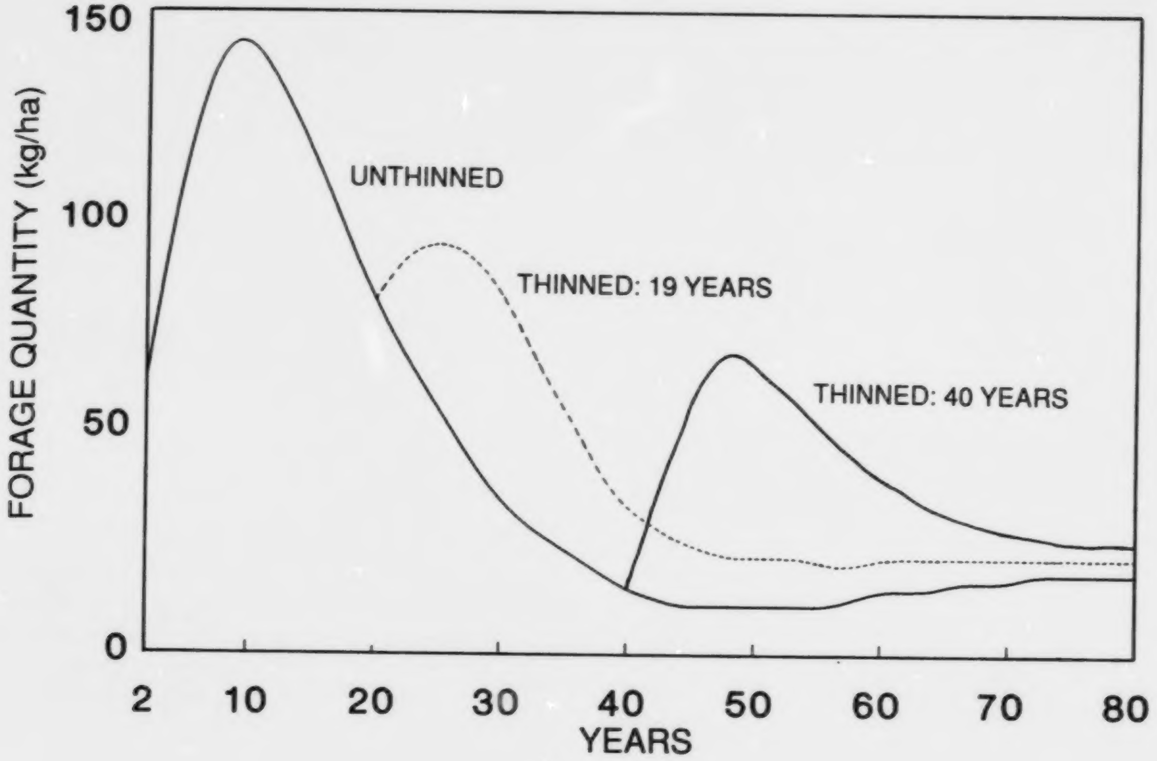


*Figure 2. The impact of thinning on production of understory plants used as forage by ungulates.*

particularly true in the case of ungulates, which require more than one sort of forest within their home range. With non-game species, such as songbirds, the principal concern is to maintain the biodiversity of the larger unit..

Factors to be considered in evaluating the potential impact of thinnings are similar to those that relate to timber harvesting. Existing guidelines regarding shoreline reserves, screening of highways, etc. should be adhered to when thinning. In harvested areas, these requirements will usually have been met by reserving uncut mature forest at the time the areas were logged. Timing of such operations is of great importance in determining the impact of forest management on wildlife. Between the third week of May and mid-July, birds are nesting and ungulates are calving. Logging and thinning should not be done during this period.

Areas of special importance to wildlife, such as known bald eagle (*Haliaetus leucocephalus*) nest sites, winter deer-yarding areas, moose and caribou calving locations, and mineral licks used by wildlife should be protected with unthinned belts of forest. The importance of maintaining snag habitat has already been mentioned. Where large tracts of country (> 5 km$^2$) are suitable for thinning, as in very large clearcuts or burns, patches of cover suitable for local ungulate species should be left unthinned and connected by unthinned travelways to other cover patches and areas of special importance. Such a system provides ungulates with thermal cover and protection from predators.

Harvesting and silvicultural operations provide excellent forage for ungulates but also provide road access to previously inaccessible areas. Although access is important in permitting harvesting of ungulates by hunters and general recreational use, it also leads to overhunting of the ungulate breeding population. If the possibility of closing roads exists, a decision must be made as to whether it is advisable to leave them open and spread hunters widely or to close as much road mileage as possible. Hunters concentrate where there is limited road access. Leaving unthinned 30- to 50-m-wide buffers along roads and also leaving such strips parallel to roads in the middle of large thinned blocks would screen vulnerable animals such as moose and caribou, as well as dispersing legal hunters and enhancing the hunting experience. Where mechanical thinning is done, at least the first two or three unthinned strips should parallel roads to screen the open strips from view. Untreated strips are also desirable along roads to reduce the fire hazard created by slash from thinning.

Provision of additional forage for browsing mammals can be a two-edged sword. The greater numbers of herbivores may cause damage to seedlings and saplings of desirable species. Early succession on clearcut areas provides an abundance of browse. The most serious pest of seedlings is the snowshoe hare (*Lepus americanus*). Depending on snow depths, hares can browse to heights of up to 2 m (Telfer 1974). Hares sometimes girdle lodgepole pine as large as 15 to 20 cm DBH by gnawing bark in spring at the ground line (W. Rugg and R. Bonar, Weldwood of Canada Ltd., personal communication). The basic habitat requirement of hares is one that provides thermal and hiding cover. Stands of softwood saplings with a crown closure > 60% are preferred cover (Radvanyi 1987). Any measures that reduce cover in and around plantations and other regenerating areas should reduce browsing damage. Chemical weeding of young stands is a form of thinning that may be helpful. Manual thinning of sapling stands is more effective for removing cover than mechanical thinning, which leaves a lot of cover in the residual strips. If an area to be planted is abutted by potential hare cover in the form of a stand of dense softwood or mixedwood saplings, hare damage can be alleviated by a heavy manual thinning. Slash from the thinning, as well as from harvesting activities, should be knocked to the ground to deprive hares of cover. Hares reach a population peak about every 10 years. At peak numbers, the juvenile hares are forced to migrate from crowded areas of good habitat and may go long distances into quite open habitat (Wolff 1980). However, they lack hiding cover in such habitat and suffer heavy mortality from hawks and owls. Peak population levels soon pass, but some tree damage is probably inevitable during these peaks. It should be remembered that there have always been hares and our forests have thrived in spite of them.

## WILDLIFE MANAGEMENT CONSIDERATIONS

If commercial thinning has many benefits for ungulates and other wildlife, it is not surprising that wildlife managers have resorted to thinning as a habitat-management tool. For instance, Shaw (1971) recommended thinning in oak (*Quercus* spp.) stands in the northeastern United States to increase production of acorns for wildlife food. He based his recommendations on data from oak stands that had been thinned at 10-year intervals beginning at age 20. At age 60, the thinned stand produced 246.4 kg/ha of acorns, compared with 177 kg/ha on control plots.

Also in the northern hardwood forest, Shaw and Ripley (1965) suggested thinning to improve deer browse in white birch (*Betula papyrifera* Marsh.) stands based on a study showing that browse yield doubled when the basal area was reduced from 25.3 $m^2$/ha to 18.4 $m^2$/ha.

I have elsewhere (Telfer 1978) recommended thinning as a means of *increasing* thermal cover in marginally suitable deer yards. Many winter yards in the Great Lakes-St. Lawrence and Acadian forest regions occur in lowland mixed forest areas. There is often an overstory of large hardwoods, especially maples (*Acer* spp.), with scattered spruce over a midstory of tolerant eastern white cedar (*Thuja occidentalis* L.), balsam fir (*Abies balsamifera* [L.] Mill.) and immature spruce. It is this thick midstory that seems to provide the necessary thermal and snow-intercepting cover for deer. A light crown thinning can be used to remove overtopping hardwoods and spruce, allowing the midstory more space and light to grow. The thinning in this situation should be very light.

Successful production of game species where forage supplies have been increased by forest-habitat manipulation must be balanced by appropriate hunting regulations. Otherwise, benefits will be lost as a result of overhunting of breeding stock. On the other hand, if hunting pressure is inadequate, severe damage may be done to the thinned stands by moose or deer.

In summary, thinning and spacing have a generally positive effect on wildlife provided such treatments are carried out with all the potential interactions in mind. However, as with all land-management activities, thinning should be planned on the basis of local knowledge of forest cover types, sites, and local climate and of what wildlife species occur locally and how they use habitat.

## LITERATURE CITED

Brace, L.G. and Golec, P.J. 1982. Silviculture statistics for Canada, 1975–80. Dep. Environ., Can. For. Serv., Edmonton, Alta. Inf. Rep. NOR–X–245. 48 p.

Bunnel, F.L. and Eastman, D.S. 1976. Effects of forest management practices on wildlife in the forests of British Columbia. p. 631–689 *in* Proc. 16th IUFRO World Congress, Division I.

Crawford, H.S. 1976. Relationships between forest cutting and understory vegetation: an overview of eastern hardwood stands. USDA For. Serv., Northeastern For. Exp. Stn., Upper Darby, Penn. Res. Pap. NE–349. 9 p.

Crawford, H.S., Hooper, R.G. and Titterington, R.W. 1981. Songbird population response to silviculture practices in central Appalachian hardwoods. J. Wildl. Manage. 45:680–692.

Crouch, G.L. 1986. Effects of thinning pole-sized lodgepole pine on understory vegetation and large herbivore activity in central Colorado. USDA For. Serv., Rocky Mountain For. Exp. Stn., Fort Collins, Colorado, Res. Pap. RM–268. 10 p.

Miller, D.R. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 3: Taiga winter range relationships and diet. Gov't of Can., Can. Wildl. Serv., Ottawa, Ont. Rep. Series No. 36. 41 p.

Pase, C.P. and Hurd, R.M. 1958. Understory vegetation as related to basal area, crown cover, and litter produced by immature ponderosa pine stands in the Black Hills. Proc. Soc. Amer. For. 1957:156–158.

Perkins, C.J. 1974. Silvicultural practice impacts on wildlife. p. 43–48 *in* J.P. Slusher and T.M. Hinckley, *Ed.* Timber-wildlife Management Symp. Proc. Missouri Acad. Sci., Columbia, Missouri, Occas. Pap. No. 3.

Radvanyi, A. 1987. Snowshoe hares and forest plantations: a literature review and problem analysis. Gov't of Can., Can. For. Serv., Edmonton, Alta. Inf. Rep. NOR–X–290. 17 p.

Samoil, J., *Ed.* 1990. Forest management statistics for Canada, 1977–78. For. Can., Northwest Reg., Edmonton, Alta. 12 p.

Shaw, S.P. 1971. Wildlife and oak management. p. 84–89 *in* D.E. White and B.A. Roach, *Ed.* Oak Symp. Proc. USDA For. Serv., Northeastern For. Exp. Stn., Upper Darby, Penn.

Shaw, S.P. and Ripley, T.H. 1965. Managing the forest for sustained yield of woody browse for deer. Proc. Soc. Amer. For. 1965:229–233.

Telfer, E.S. 1972. Understory biomass in five forest types in southwestern Nova Scotia. Can. J. Bot. 50:1263–1267.

Telfer, E.S. 1974. Vertical distribution of cervid and snowshoe hare browsing. J. Wildl. Manage. 38:944–946.

Telfer, E.S. 1976. The impact of forest management on wildlife in the northern and eastern forests of Canada. p. 613–630 *in* D. Mlinsek and O. Borset, *Ed.* Proc. 16th IUFRO World Congress. Division I, Oslo.

Telfer, E.S. 1978. Silviculture in the eastern deer yards. For. Chron. 54:203-208.

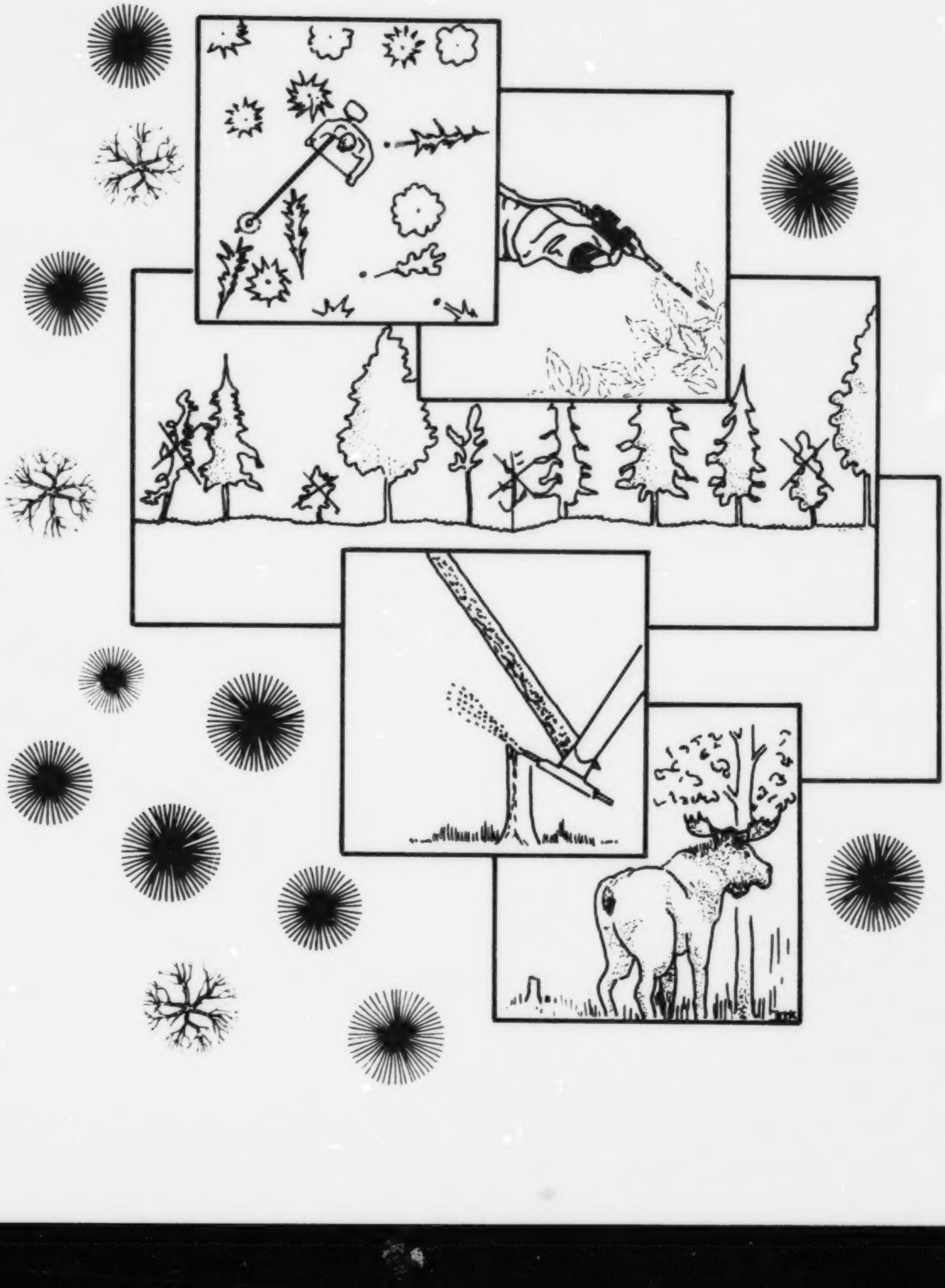
Thomas, J.W. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA For. Serv., Washington, D.C. Agric. Handbook 553. 512 p.

Trottier, G.C., Carbyn, L.N. and Scotter, G.W. 1989. Effects of prescribed fire on small mammals in aspen parkland. p. 179–182 *in* T. Bragg and J. Stubbendieck, *Ed.* Proc. 11th North American Prairie Conf. Nebraska Printing, Lincoln, NE. 293 p.

Wolff, J.O. 1980. The role of habitat patchiness in the population dynamics of snowshoe hares. Ecol. Monogr. 50:111–130.

Zack, A.C. 1987. Interdisciplinary development of caribou habitat management guidelines: the role of the silviculturist. p. 25–55 *in* Proc. Nat'l Silvic. Workshop, Silviculture for all resources. 11–14 May 1987. USDA For. Serv., Timber Manage. Staff, Washington, D.C. 322 p.

# SESSION IV
## *Spacing and Thinning Operations*



# REDUCING STEM DENSITY WITH HERBICIDES: WHAT ARE THE OPTIONS?

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## ABSTRACT

Foresters are currently able to reduce the number of stems in a stand by using a suitable combination of herbicide type, rate, timing and application equipment. The basal-bark, cut-stump and single-stem injection methods of application are economical options for treating stands of low to medium density.

In recent operational trials in Maine, a method of application for reducing stocking in high-density, naturally regenerated spruce-fir stands was examined. Aerial application of herbicides with a precision delivery system such as the Thru-Valve Boom[1] has had some initial success in this situation.

## RÉSUMÉ

Actuellement, on peut réduire le nombre de tiges d'un peuplement par la combinaison convenable de l'herbicide (type, doses, moment de l'application) et du matériel de traitement. Le traitement arboricide cortical, le traitement des souches et l'injection dans la tige sont des méthodes économiques pour les peuplements de densité faible à moyenne.

Dernièrement, dans le Maine, on a expérimenté en grand une méthode pour réduire le nombre de tiges dans les peuplements d'épinettes (*Picea* spp.) et de sapins (*Abies* spp.) naturellement régénérés de forte densité. L'application d'herbicide du haut des airs au moyen d'un système de précision tel que la rampe Thru-Valve[1] a été couronnée d'un certain succès initial.

## INTRODUCTION

Dr. Max MacCormack from the University of Maine was intended as the original speaker for this particular presentation, but was unable to be here because of a previous commitment. I would like to extend his greetings to everyone and hope I can be a reasonable replacement for him. Personally, I would much rather listen to him speak.

DowElanco might not be a familiar name to you. About 18 months ago, Dow Chemical and Eli Lilly, two large, multinational companies based in the United States, decided that their long-term business potential would be better if they consolidated their agrichemical businesses. They decided to form a joint venture, which is 60% owned by Dow Chemical and 40% by Eli Lilly. The name of this new company is DowElanco.

This consolidation or joint venture makes DowElanco the largest U.S.-based plant science company, and the fifth-largest agrichemical company in the world, behind four European companies. Down the road, there will be fewer players in the business and fewer products in the marketplace. With new, stringent pesticide registration requirements, many new products will not pass the rigid testing that is required before they reach the marketplace.

My main responsibility in the forestry-related part of my job is to undertake herbicide and insecticide research and development programs for DowElanco Canada. We look forward to getting back into this market with the registration of a new product called Release® Silvicultural Herbicide.

I will begin my presentation by discussing a quasi-operational experiment that was conducted in the state of Maine a couple of years ago. Max MacCormack is very proud of this effort, since he was the one who initiated it. There is a problem in the state of Maine, as in other parts of North America, with overstocked, naturally regenerated coniferous stands. People are looking at ways to reduce that stocking in the most appropriate manner. These sites may have up to 100,000 stems/ha and must be reduced to densities of between 2,000 and 5,000 stems/ha. Some of these sites may be very inaccessible, and road access may be nearly impossible.

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[1] Trademark of Waldrum Specialties, Inc., Doylestown, Pennsylvania.

## STRIP THINNING OF CONIFERS

In the southern part of Maine, planting is now becoming more popular. In the northern half of the state, however, silvicultural management of naturally regenerated stands is taken very seriously, as the primary focus in this area is the pulp and paper industry. Around 1980–1981, a particular aerial spray application system called the Thru-Valve boom (Fig. 1) was developed in the States.

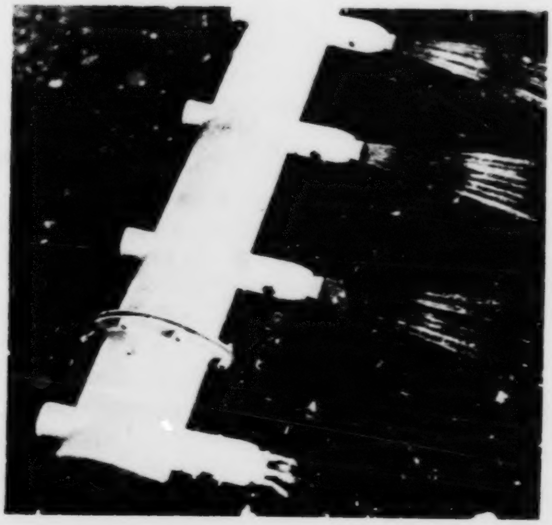

*Figure 1. The Thru-Valve boom aerial spray applicator.*

The Thru-Valve boom is unique in that spray droplets are emitted from the trailing edge of the airfoil boom at very low pressures. Laminar air flow causes the development of long strings of spray that break into primary droplets, then into secondary droplets, and the formation of excessive windshear is eliminated; this minimizes the production of fine aerosols, which are more susceptible to drifting off target. In effect, you get an application in which these particular spray particles drop to the ground under the influence of gravity, producing a knife-edge effect along either side of the spray swath; that is, the edges of the swath are sharply defined, with no "feathering". This greatly reduces the potential for drift or off-target deposition of the herbicide. This boom was primarily developed for use on right-of-ways, where chemical trespasses cannot be tolerated. It is also not economically feasible to put the material where it is not intended to go. Max had an idea that he called "conifer strip-thinning", which could be used on these large, wide-open expanses of overstocked, naturally regenerated spruce (*Picea* spp.) and fir (*Abies* spp.) stands in northern Maine. He decided to use this particular boom system, which is configured to form 1,000- to 2,000-μm-diameter droplets.

Max wanted to conduct an experiment to see if these coniferous stands could actually be thinned by blocking off certain sections of the nozzles on the boom to obtain a type of banding or stripping effect when the herbicide was applied. He began by blocking off enough nozzles on the boom to produce a 4-foot-wide (1.2-m) area of treated brush and conifers and an 8-foot-wide (2.4-m) area of leave strip on the ground (Fig. 2). This particular application required a good guidance system, and the knife-edge effect of the Thru-Valve boom would allow this to occur operationally and minimize the chances of not receiving the desired effect.

In the experiments, it was found that with a flying height of about 70 feet (21 m) and an application speed of about 25 to 30 miles (40 to 48 km) per hour, there were no differences in spacing when the swath reached the ground. Hence, 2 years after application, the banding effect in Figure 3 was produced. Herbicide application normally took place 3 to 5 years after harvesting, and the remaining strips will be precommercially thinned at about 12 years of age.

Cut-stump applications are becoming more and more popular in forestry.

## APPLICATION OF HERBICIDES TO CUT SURFACES

I would now like to discuss something that might be more familiar to you — the use of previously registered herbicides for application on cut surfaces and various application techniques to perfect this methodology. A few of the methods you may be familiar with are the hypo-hatchet injection method and the frill or girdle method. (In the hypo-hatchet method, a hatchet is used to cut the tree's bark at right angles to the stem, girdling the tree, at the same time as the herbicide is injected; in the frill method, herbicide is applied with a spray bottle instead of being injected.) Some of the older methods were probably a bit more primitive. One of the new innovations, developed primarily by B.C. Hydro, is the gel-cap method. The gel-cap is a plastic capsule with a small screw in the center in which a jellied formulation of herbicide is placed. The capsule is screwed through the bark

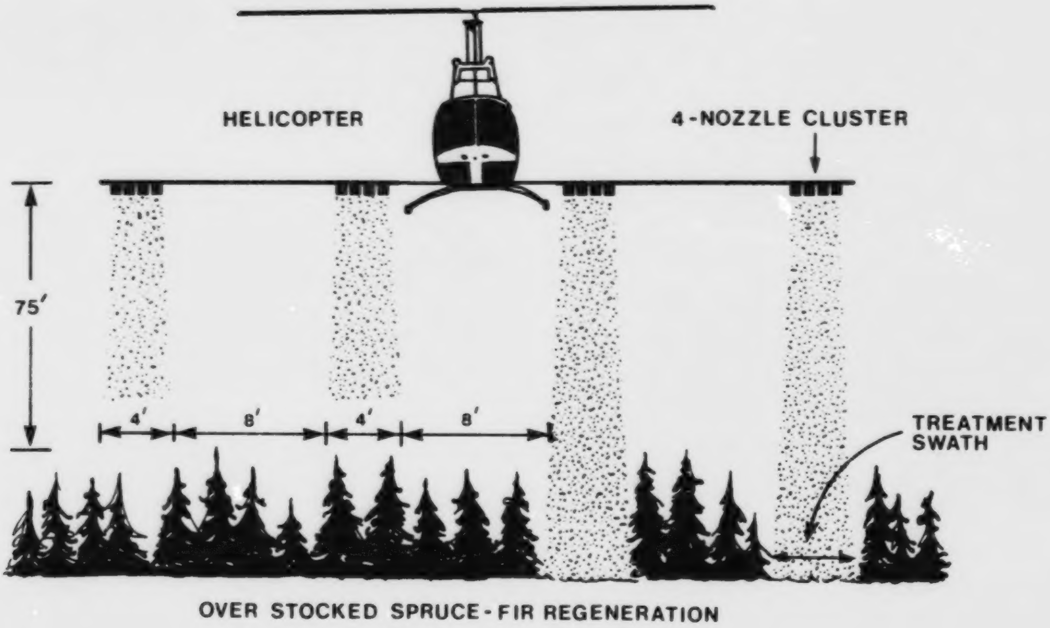

*Figure 2. Precise application of herbicide bands using the Thru-Valve applicator.*

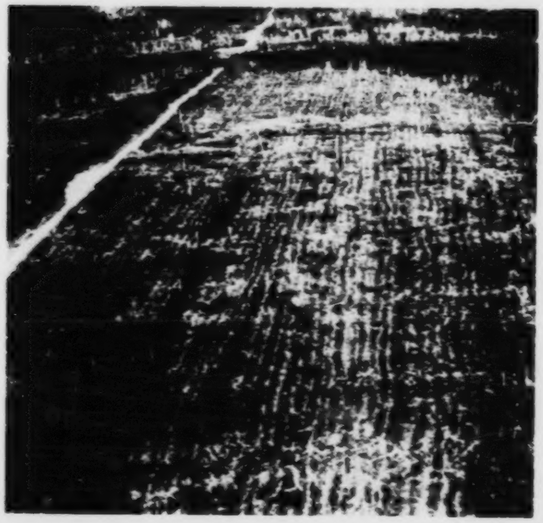

*Figure 3. Banding effect produced by the herbicide application in Figure 2.*

into the cambial area of the tree (Fig. 4). The edge of the capsule cuts through the bark, allowing the herbicide to move into the xylem and phloem and be translocated. A recent development is the use of spent 22-caliber bullet rim-fire cartridge cases, which contain the herbicide and are injected into the tree (Fig. 5). This is a prototype of the original injector system and I believe the newest development allows for up to 300 capsules per injector and a dose of approximately one capsule or bullet for every 5 cm of diameter at breast height (DBH), depending on the herbicide product chosen.

Aerial applications with the Thru-Valve boom are used not only for spacing operations but also for release of conifers and application of the herbicides in and around sensitive or buffer zones. Some of the reasons foresters would consider utilizing cut-stump application are listed here.

The most conventional way of applying herbicides by means of the cut-stump method is to cut the brush with power saws or brush saws, and then paint the surface of stumps with the herbicide mixture. The herbicide is normally in a liquid form and is applied with a roller, paint brush, spray bottle or even a backpack sprayer. A new innovation under development attempts to minimize the potential adverse impact on adjacent ground vegetation by ensuring that the material is applied to the cambial area of the stump. A conventional backpack spray application tends to overspray the stump area. To prevent this

*Figure 4. The gel-cap method of herbicide application.*

we have added a material called methocel, a thickener with the consistency of a milkshake that is used in the food industry, to the herbicide. The mixture is added to a brush attachment on the end of a spray wand on a backpack. The material is applied to the surface of the stump, so there is no need to carry around a liquid for spraying and all the material is applied only to the place it is supposed to go..

There has been a lot of trial work with herbicide attachments to brush saws and many of you are familiar with these, as they are being used operationally in many parts of Canada and the United States. The herbicide is not actually injected into the stump, but spreads across the surface where the particular tree has been cut with the brush saw.

## BASAL-BARK APPLICATION METHODS

A method that has been around for a number of years but that has not gained as much popularity in Canada as in the United States is basal-bark application. There are some products on the market now and few under development that will actually penetrate the bark itself without requiring a cut through the surface. The material then moves into the xylem and phloem and is translocated to the growing points of the tree.

In addition to the cut-stump or cut-surface application techniques, the most popular technique in recent years has been the conventional basal application method. This involves a very low concentration of herbicide applied in a larger carrier volume with kerosene. The main drawback of this technique, of course, is that backpacks need to be refilled frequently to effectively treat all the brush when you have a long distance to travel into the area to be treated.

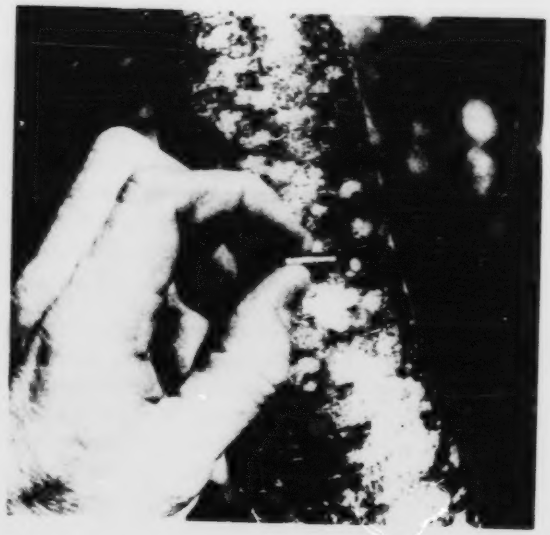

*Figure 5. The 22-caliber bullet method of herbicide application.*

One new innovation that right-of-way vegetation managers have adopted is the manner in which basal applications are applied. Applicators do not spray until runoff and pooling at the base of the stem occurs; instead, they cover the surface to be treated until it is just wet. This low-volume method tends to reduce the amount of carrier required, and has been extremely effective with all the species we have tested it on in Canada using Release® — everything from big-leaf maple (*Acer macrophyllum* Pursh) in the west to sugar maple (*A. saccharum* Marsh.) in the east, and everything else in between. With this method, the workers carry a higher concentration of the herbicide in their backpacks and can treat a greater area with a single backpack.

Thin-line application has been proposed as another good alternative. With this technique, the undiluted herbicide is carried in a backpack, and a thin stream is applied around the perimeter of the individual stem being treated. This method allows the material to move down the stem, penetrate the bark, enter the cambial region, and then move to the locations where it can control the plant.

In a naturally regenerated spruce-fir stand near Fredericton, New Brunswick, at the University of New Brunswick woodlot, we conducted a trial in cooperation with the Maritime Forest Ranger School in an attempt to use Release® to control white birch (*Betula papyrifera* Marsh.), gray birch (*B. populifolia* Marsh) and red maple (*A. rubrum* L.) clumps. Various concentrations and timings were used. We applied the material in the dead of winter, and have had extremely good results. We found that we could successfully treat trees of up to 15 cm DBH with this technique.

On Vancouver Island, some of the other products registered for aerial application broadcast use in forestry are very effective on the *Rubus* component of the competition, such as salmonberry and thimbleberry, but not quite as effective on the big-leaf maple. We conducted an experiment in an attempt to control coppice growth of the big-leaf maple clumps, in which a basal application of Release® was carried out with different timings and rates of applications; we haven't yet seen any regrowth. This application can be done in any month of the year.

In a trial conducted in cooperation with the Ontario Ministry of Natural Resources near Matheson, Ontario, we applied the herbicide material in December and the only limiting factors were snow depth and the ability of the workers to move about the site. We found that cold temperatures do not cause the product to thicken and that workers actually liked to work at this time of year. In winter, the workers can move around plantations more easily and they are better able to see the tree they are treating because they do not have herbacious layers in their way.

## CONCLUSION

In conclusion, there is a wide variety of herbicide-application techniques currently available and under development and these will enable foresters to reduce overall stand stem densities and leave desirable young conifers with "Space to Grow".

# WORK PLANNING AND A TECHNIQUE FOR USING CLEARING SAWS IN PRECOMMERCIAL THINNING

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## ABSTRACT

In coniferous or deciduous stands, precommercial thinning can be done effectively with a clearing saw. Before the work is done, one must decide what the end product will be. Selection of crop trees should be based on stem quality and other factors rather than on stand density alone. For example, in pine (*Pinus* spp.) stands, differences in tree height should be minimized and openings should not be enlarged by removing trees of poorer quality. In addition to thinning itself, personal safety equipment and the attributes of a good clearing saw are described. The need to size a saw to the job and to select the correct blade is emphasized, and the principles of directional felling are discussed.

## RÉSUMÉ

Dans les peuplements de conifères ou de feuillus, l'éclaircie précommerciale peut se pratiquer d'une manière efficace à l'aide d'une scie à dégagement. Avant d'entreprendre les travaux, il faut décider de la nature du produit final. La sélection des arbres du peuplement final devrait être basée sur la qualité des tiges et d'autres facteurs plutôt que seulement sur la densité du peuplement. Par exemple, pour les peuplements de pin (*Pinus* spp.), les différences de hauteur des arbres devraient être minimales et l'ouverture du couvert ne devrait pas être élargie par élimination des arbres de moins bonne qualité. Outre l'éclaircie elle-même, l'équipement personnel de sécurité et les caractéristiques d'une bonne scie sont décrits. La nécessité de dimensionner une scie en fonction des exigences de l'opération et de sélectionner la lame correcte est soulignée et les principes de l'abattage directionnel sont examinés.

## INTRODUCTION

Nordfor training and consulting is a member of the Electrolux Motor Group. We are the smallest company in the group, comprising 10 instructors. Most of our training is carried out in Sweden, but we have also conducted major training projects all over the world. In the last 5 years we have, for instance, been in South America, the United States, West and East Europe, Africa, Asia, Russia, Great Britain and Ireland.

I have been working as an instructor for more than 7 years and I have specialized in precommercial thinning, manual and mechanized commercial thinning, and manual and mechanized clearcutting. In the past year, I have been in Newfoundland and Quebec, training instructors in precommercial thinning, commercial thinning and clearcutting.

The first principle addressed in our training is an understanding of the proposed operation. Based on our initial findings, we design the program together with our client. The program includes the training of all personnel engaged in the operation, with most of the training taking place in the field. Our training of precommercial thinning instructors takes about 2 weeks for personnel experienced in the correct methods of spacing and thinning. In week one, training is given in work techniques and patterns, and crop-tree selection is explained; in week two, the students are trained on how to train others.

In the following sections, the justification for spacing and the principles of clearing will be addressed. Attributes of the clearing saws will be explained, along with appropriate precautionary measures that must be recognized. All figures are based on photographs in the brochure *Husqvarna Forestry Technique for Clearing Saws.*

## DECIDE WHAT IS DESIRED

Many questions must be answered before spacing and thinning work is started. Before conducting thinning in any stand, decide what the end product in your forest will be. Which species gives the best production on a particular site? Do you want deciduous or coniferous trees? Do you want as much volume as possible or a short rotation? Is your species good for sawlogs, particularly good-quality sawlogs? Do you have a market for the materials that you plan to remove? Will you do any commercial thinning in the future? What harvesting method do you think will be used in 35 to 40 years?

## CROP-TREE SELECTION

Why clear? "Clearing" means the removal of the small saplings of an undesirable species or of no commercial value. Clearing allows quality timber a better chance to develop properly. The crowns and root systems are allowed to spread unhindered, and their use of nourishment from the ground and sunlight is improved. In this way, the residual crop trees can grow larger and mature more quickly.

When the crop trees are selected, the silvicultural worker should strive for the desired density (i.e., the correct number of residual trees per hectare). It is not necessary that all crop trees be spaced systematically, but always recommend an optimum distance between crop trees and try to select fast-growing, good-quality trees. Try to reduce differences in height, especially in pine (*Pinus* spp.) stands. If you have openings in the stand, do not make them larger; leave more trees (a higher density) around openings!

While clearing, some environmental considerations must be addressed. If feasible, do not remove trees or bushes that bear fruits, as these can be sources of food for wildlife. Do not clear on fragile sites with steep slopes or in certain wetlands, as the recoverable timber probably does not justify the cost and the risk of damage to the site can be high. Remember to keep all pathways and ditches clean.

## CLEARING SAW EQUIPMENT AND SAFETY

A clearing saw is a motorized tool and must be treated with respect. Not only must the operator take care in handling the machine, but he must protect himself from possible injury due to falling trees and flying debris (Fig. 1). An operator should always wear a hard hat that has ear and eye protection and carry a first aid kit. Clothing should be appropriate for the weather conditions, but be lightweight and strong. Safety trousers are advisable. It is important to use comfortable, lightweight boots with a deep tread on their soles. The use of gloves is also recommended. The operator should always be conscious of safety and never operate a clearing saw near others.

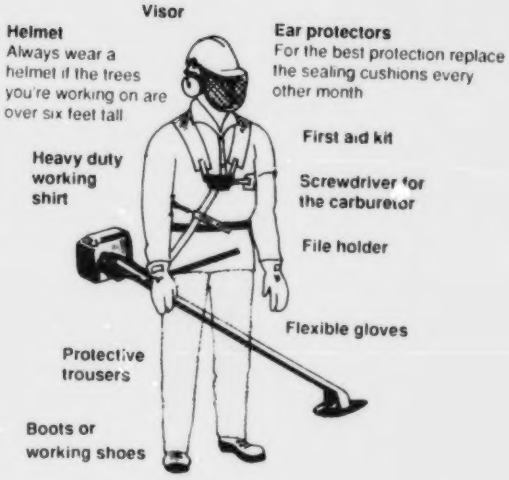

Visor
Helmet
Always wear a helmet if the trees you're working on are over six feet tall
Ear protectors
For the best protection replace the sealing cushions every other month
First aid kit
Heavy duty working shirt
Screwdriver for the carburetor
File holder
Flexible gloves
Protective trousers
Boots or working shoes

*Figure 1. Recommended safety gear for workers with clearing saws.*

### Clearing-saw Harness

The harness used for carrying the clearing saw is fully adjustable and is designed to distribute the weight of the clearing saw on one's shoulders. There should be relatively little weight in the operator's hands. The harness should be adjusted to the satisfaction of a specific operator. For example, the appropriate height of the hook is about 10 to 15 cm below the top of the hip bone. Once adjusted, the saw should hang comfortably (Fig. 2) and the harness should have a safety release to help prevent any accidents.

### The Clearing Saw

Before choosing a clearing saw, ascertain the diameter of the trees to be cut. The size of the blade will be determined by the average tree size. For small-diameter stems, a lightweight clearing saw with less than a 50-cc-displacement engine and a 200-mm blade is suitable. For larger material, a 225-mm blade is more suitable, but this requires a clearing saw with a displacement greater than 50 cc.

It is also important that the saw has an angle of 30° or less between the blade and shaft. Proper sharpening and setting of the blade is required in order to be efficient, and it must be done at least three or four times a day, even if you don't hit stones.

The handlebars must be adjustable so that any operator can work comfortably. Always adjust and balance the saw properly. The saw should be balanced in such a way that the blade will not catch the ground even if the gas tank is empty (Fig. 2).

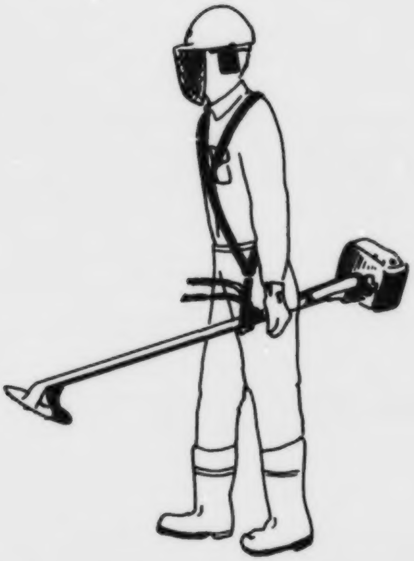


*Figure 2. Correct adjustment of the clearing-saw harness.*

Specific techniques for clearing have been developed. To be effective, the operator must understand the attributes of the blade. Because the blade rotates, it has different cutting characteristics depending on the part of the blade being used. If the face of the blade is visualized as a clock seen from the operator's position, one must remember that the 12 o'clock to 3 o'clock sector is the dangerous "kick-back" zone (Fig. 3). Otherwise, the 12 to 6 o'clock side of the blade is used for fast cutting for either left-handed or right-handed felling. The 6 to 12 o'clock side of the blade is used for precision cutting, and for felling larger trees.

## DIRECTIONAL FELLING

The goal of directional felling is to enable an operator to fell trees precisely into the most desirable locations using only the clearing saw. For small trees, less than 1.3 m in height, an operator does not need to be concerned with directional felling.

Larger trees should be felled in such a manner that they will not lodge against others and create a safety hazard. By tilting the blade in different directions and using different parts of the blade when cutting, the operator can control where he wants the trees to fall (Fig. 4). Trees with stump diameters ranging from 3 to 8 cm can be felled with a single cut (using a 225-mm blade).

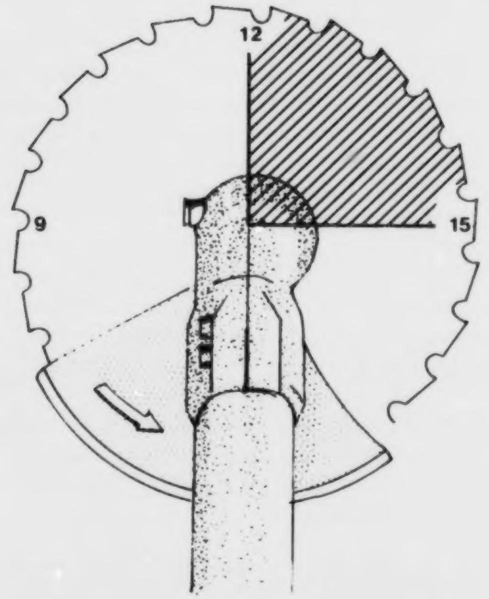
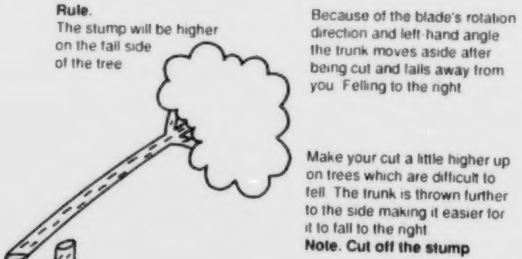


*Figure 3. A typical clearing-saw blade, with the "kick-back" zone indicated.*



**Rule.**
The stump will be higher on the fall side of the tree

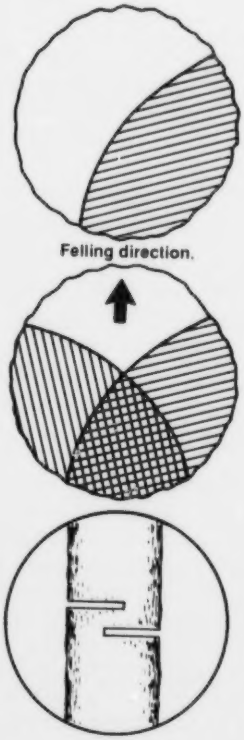
Because of the blade's rotation direction and left-hand angle the trunk moves aside after being cut and falls away from you Felling to the right

Make your cut a little higher up on trees which are difficult to fell The trunk is thrown further to the side making it easier for it to fall to the right
**Note. Cut off the stump**

*Figure 4. Directional felling.*

Trees with a stump-height diameter of from 8 to 15 cm must be cut from two sides (Fig. 5). If the two cuts overlap, there is less chance for binding of the blade. When felling trees with stump diameters greater than 15 cm, the operator must use a cut with an open notch (Fig. 6).

While cutting, use a work pattern that allows the operator to fell the trees into areas that have already been cut. In this manner, the operator does not need to walk over stems that have already been felled.



First, cut half the trunk diameter; use the 6 o'clock to 12 o'clock side of the blade.

Next, cutting from the other side of the trunk about an inch above the first cut, saw again to the center of the trunk. Use the 12 o'clock to 6 o'clock side of the blade.

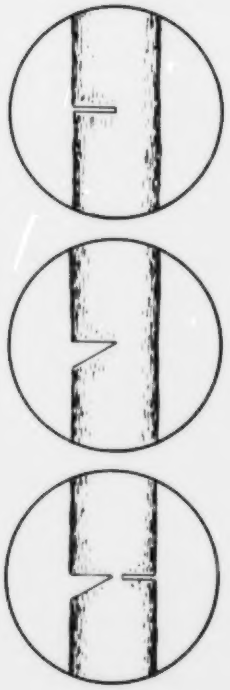
If necessary, saw off the hinge.

*Figure 5. Use of overlapping cuts to fell trees with diameters from 8 to 15 cm.*

The width of the strip being harvested will vary depending on the density of the stand, the size of trees, and whether the site has steep slopes or is flat. Always start cutting at the bottom of the slope. Always move across the slope and use the wind to your advantage. The wind should help trees to fall into previously thinned areas. As well, plan work so your fuel does not run out when you are far from your gas can.

## SUMMARY

With effective work planning, proper cutting techniques and a thorough knowledge of how to get the most



1. use the 6-12 o'clock side of the blade for the following

2. Make the steering cut horizontally

3. Cut out a wedge.

4. Make the felling cut from the other side of the trunk. Be sure to use the 6-12 o'clock side of the blade

*Figure 6. Procedure for felling trees with diameters greater than 15 cm.*

of the clearing saw, precommercial thinning can be strain-free, interesting and rewarding work. Day by day, one begins to see a nice stand of trees developing.

Our experience from years of training precommercial thinning workers suggests that even if the people have been working a long time with clearing saws they usually do not have good work technique nor do they adhere to a good work pattern.

With training you can achieve better quality work, higher person-day productivity, lower overall costs, less down-time due to equipment malfunctions and more highly motivated experts who will consider themselves professionals.

# TECHNOLOGY FOR MECHANIZED THINNING

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## ABSTRACT

The paper provides an overview of the state of mechanized precommercial and commercial thinning in central and eastern Canada, including the currently available equipment and recent attempts at mechanization. The status of mechanized thinning in Denmark, Sweden and Finland is reviewed, highlighting the technology's potential application in Canada. Some concerns and constraints regarding the development and application of equipment for thinning are also discussed.

## RÉSUMÉ

L'auteur présente un aperçu de l'éclaircie mécanisée, précommerciale et commerciale, dans le centre et l'est du Canada. Il rend compte notamment de la situation en ce qui concerne l'équipement actuellement disponible et des tentatives récentes de mécanisation. Il examine la situation dans les pays scandinaves, en mettant l'accent sur les techniques qui pourraient être appliquées au Canada. Il se penche sur des problèmes et des contraintes associés à la mise au point et à l'utilisation de l'équipement pour l'éclaircie.

## INTRODUCTION

Precommercial and commercial thinning are both stand-tending practices that have the potential to be mechanized. However, for a variety of reasons, mechanized operations are virtually nonexistent in Canada. The causes for the lack of mechanization, the current technology and the scale of operation are vastly different for precommercial and commercial thinning.

For the purposes of this paper, precommercial thinning is a stem-reduction operation practiced in stands of natural regeneration or that have resulted from direct seeding. It includes removal of crop and non-crop species. Conversely, cleaning is defined as the mechanical release of crop trees in young plantations. Commercial thinning involves the harvesting of wood at a profit and is being practiced in both naturally regenerated stands and plantations. This paper addresses primarily the mechanization of precommercial and commercial thinning in softwood stands.

## STATE OF MECHANIZED THINNING IN CENTRAL AND EASTERN CANADA

### Precommercial Thinning

Precommercial thinning is a well established and growing practice, although there are differences among provinces. The current annual level of precommercial thinning across Canada is still only 60,000 to 70,000 ha. However, there are extensive areas of overly dense regeneration that are left solely because of limitations on available resources. Despite the potential, there is no operational mechanized thinning at this time, despite attempts to mechanize the operation during the last 40 years. A review of past successes and failures can be found in Ryans (1988).

Most precommercial thinning is done "motor manually" with clearing saws. Chainsaws are also used if the operator is unwilling to make the extra investment or if tree size limits the performance of a brush saw. However, there is no doubt that the brush saw is the safest and most efficient motor-manual tool under central and eastern Canadian conditions.

The main disadvantage of the motor-manual method using brush saws is the high cost of treating stands. Even a skilled brush-saw operator's productivity is highly sensitive to stand density, as shown in Figure 1. In addition, a good training program and a couple of years' experience are required to become a productive operator.

### Equipment

A variety of integrated brush-cutting machines and attachments are available. To date, none have entirely

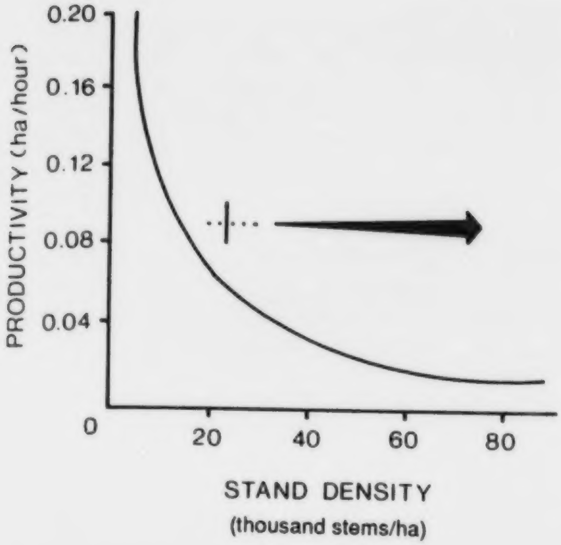


*Figure 1. A typical productivity curve for motor-manual spacing.*

matched our requirements or expectations (Smith 1987, Ryans 1988), and some require more extensive testing.

The following is a brief review of the equipment used in strip-thinning trials during the 1980s and of potentially useful machines. Included are the more promising off-the-shelf machines and some recent development efforts.

Vertical-shaft equipment has been used in the form of attachments or integrated with a prime mover. Integrated machines, such as the Kershaw and Hydro-Ax, have been tested in most regions across Canada. The Kershaw 10-8 has a twin vertical-shaft, flexible-knife cutting head. The operator has excellent visibility of the cutting head. The prime mover is only slightly wider than the 2.36-m-wide cutting head. Ground pressure is fairly high. Unfortunately, the 10-8 model is no longer in serial production and the next model, the 10-10, is much too wide to create a suitable cut strip. A model 10-8 was used operationally for strip spacing of balsam fir (*Abies balsamea* [L.] Mill.) in Maine in 1986. Herring (1981) also reported experimental use of the machine in British Columbia for precommercial thinning.

The Hydro-Ax Rotary-Ax is available in various models. Most models have a single vertical-shaft cutting head. A flexible knife is mounted on each end of a rotating blade. Some users have replaced the blade with a disc. The smaller model 300 is underpowered (H. Ross, Stora Forest Industries, Port Hawkesbury, Nova Scotia, personal communication). Models with suitable power (the 520, 620 and 720 series) have a 2.45-m-wide cutting head, but the prime mover is wider than the cutting head unless equipped with narrow (18.4 in.) tires that result in high ground pressure.

Trials of the machine in Canada over the past 10 years are reported by Herring (1981) and Hedin (1987) in British Columbia, and Ross (ibid.) in Nova Scotia. Seymour et al. (1984) studied a model 520 used in balsam fir stands in Maine and the machine was used operationally until 1987.

A Rotary-Ax attachment has also been installed on modified tracked, front-end loaders. The Track-Ax was tested in 1987 and 1988 by the B.C. Ministry of Forests and Lands (MOFL) to examine the performance of a tracked machine on slopes of 30% or more (Forrester 1989). The machine demonstrated the ability to meet the MOFL standards.

There are a number of boom-mounted vertical-shaft cutting heads that have been or are being tried in precommercial thinning. The cutting head of the Weldco boom-mounted flail consists of a rotating disc on a vertical shaft with three free-swinging blades. The flail was mounted on the conventional articulated boom of a Caterpillar 205 excavator. A brief trial was conducted in the fall of 1986 on a steep slope with heavy debris in interior British Columbia (Hedin 1987). Productivity was poor, but it was felt that there may be some future potential for the concept. Cutting heads, similar to those of the Weldco units, are produced by a number of manufacturers across Canada.

Presently, excavators with flail and saw-type cutting heads are being used for precommercial thinning on an experimental basis in Quebec and Maine.

The TSS circular saw mounted on a 19-kW Komatsu PC-20 mini-excavator was first tried for strip thinning in 1989 (St-Amour 1990). In a brief evaluation by the Forest Engineering Research Institute of Canada (FERIC), the machine had a productivity rate of only 0.08 ha/PMH. However, the machine lowered the overall total manpower requirement, including that of the motor-manual spacing along the leave strips.

A number of forest companies in the Lac St-Jean region of Quebec, New Brunswick and Maine were in the process of running trials in 1990 with Munger brush cutters to mechanize their precommercial thinning operations (Fig. 2). The new Munger SMC-400 has a vertical-shaft cutting head with two free-swinging

*Figure 2. Munger SMC-400 brush cutter mounted on a small excavator.*

blades. A unique feature of the model 400 is the rotating (360°) rock guard. Rotating the rock guard 90° permits the blades to cut trees while extending the boom forward. The prime movers being used for precommercial thinning are 1.8-m-wide Kubota TBC 101 excavators, which have been specifically modified for the application.

The first Usinaxe DAG-346 brush cutter was introduced in 1989 and used on various brush-clearing operations and for precommercial thinning. The Usinaxe comprises a vertical shaft with three tiers of discs and two free-swinging blades on each disc. A smaller model is currently under construction that will be used for precommercial thinning in aspen (*Populus* spp.) stands in the Abitibi-Temiscamingue region.

A D&M Slashbuster 360 is being used operationally in Maine for precommercial thinning. The Slashbuster head is a rotary cutting disc with fixed teeth, and rotates at a relatively slow speed (400 rpm) in comparison with other cutting mechanisms. The head is mounted on a modified Hitachi 150 excavator (Meyer 1990).

A vertical-shaft, twin-saw cutting attachment was built by Weldco in cooperation with FERIC's Western Division, and was tested in British Columbia in fire-origin lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) stands. The original cutting head was mounted on a hydrostatic-drive tracked loader to better negotiate the steep slopes and difficult debris conditions found in B.C. (Hedin 1990). At the present time, the head is being modified to be mounted on the boom of an excavator.

Horizontal-shaft cutting heads are usually available only as attachments. As well, the majority of these heads are made to be mounted on a farm tractor. Since there have been few units available for testing and more extensive modifications are required for mounting them on a suitable carrier, the experience with horizontal-shaft cutters in Canada has been limited.

In an operational development trial initiated through the Canada–Saskatchewan Forest Resource Development Agreement, Forestry Canada tested a Seppi Forst brush cutter to demonstrate the potential of precommercial strip thinning with motor-manual follow-up in fire-origin jack pine (*Pinus banksiana* Lamb.) stands. The machine cut strips through an 11-year-old stand with an average height of 2 m and densities ranging from 30,000 to 40,000 stems/ha (Sidders 1989).

The Seppi model 175 was hydrostatically driven from a modified Versatile 276 bidirectional tractor. The 75-kW power take-off (PTO), 4-wheel-drive tractor has a hydrostatic-mechanical transmission. The width of the tractor is 2.4 m, and the cutting head is 2.1 m wide including belt-drive housing and skids. Damage was being caused by the sides of the tractor during the operation, primarily by the tires, but the damaged stems were removed during the subsequent motor-manual operation.

Although not designed for brush cutting, a Hydro-Ax flail delimber has been used for precommercial thinning on an operational basis in Maine. The cutting head consists of short lengths of chain spaced along a horizontal drum. The flailing chain has the potential to remove limbs close to the ground and is less sensitive to damage when striking rocks. It could be used as the main cutting head in front of the machine or as a trailing, secondary head to clean off the live, lower limbs.

A Hydro-Ax 520 chain flail is also being tested for early precommercial thinning (age 3–4) in balsam fir stands in Nova Scotia that, on average, are overstocked but that contain overly dense patches. The strip thinning treatment is to be followed by in-fill planting in the openings and along the "cut" strips. Modifications to the flail are being tried to increase the mortality within the cut strip. Potential cutting devices include various combinations of chain, wire rope, cutting tips, and thick rubber strips. A motor-manual treatment will be done when the stand reaches the conventional age for spacing (10 to 12 years). Trials are underway to determine the feasibility of this method to treat partially stocked sites.

The Timberwolf 90 is a 2.45-m-wide, horizontal-shaft brush cutter with a self-contained, 203-kW auxiliary engine (Fig. 3). One unit, mounted on a hydrostatic-drive tracked loader, was tried for strip thinning in British Columbia in 1989 (Hedin 1990).

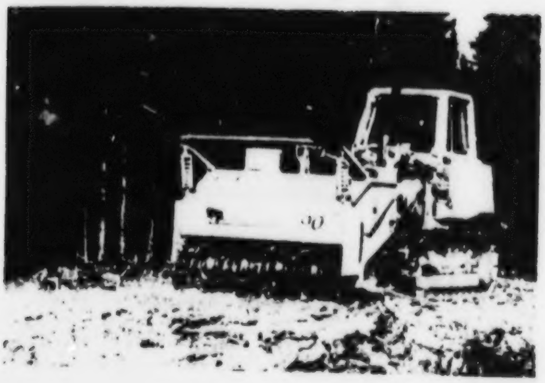


*Figure 3. The Timberwolf 90 brush cutter.*

### Methods

In target stands with more than 20,000 stems/ha, the most promising method with current technology appears to be a semi-mechanized system; that is, a combination of strip thinning followed by a motor-manual treatment in the leave strips. This method applies the stem-reduction advantage of a machine to part of the stand yet allows for a brush-saw operator to make the final selection of crop trees. The proportion of the stand cut with the machine will depend upon the relative width of cut and leave strips, and on the stand density. However, it is doubtful that more than 50% of the stand can be removed mechanically because too many of the potential crop trees would be lost.

Machines with a boom have the potential to mechanize the entire operation. Nevertheless, selecting crop trees with such machines has often been found to be too time consuming or damage to crop trees has been excessive. Therefore, boom-mounted brush cutters have usually been used to cut corridors only.

### Commercial Thinning

Interest in mechanized thinning has increased, as some local wood shortages are predicted. Nevertheless, very little thinning, manual or mechanized, is currently being done, and the majority is on private land.

The level of mechanization is usually low. Felling, delimbing and bucking are done with a chainsaw, although some farm tractor-mounted processing units are in use, such as the Nokka 400. Extraction of the wood is done with small forwarding vehicles (e.g., Bombardier J-5, F4 Dion), trailers pulled by farm tractors, or small skidders or farm tractors equipped with winches.

The only ongoing mechanized commercial thinning in Canada involves two machines: Makeri 33T harvesters and Nokka Joker single-grip harvesters, used primarily in red pine (*Pinus resinosa* Ait.) plantations in Ontario. Some other Nordic (primarily Danish, Swedish, and Finnish) single-grip harvesters have also been used, but only for brief trials.

## STATE OF MECHANIZED THINNING IN NORDIC COUNTRIES

### Precommercial Thinning

In Sweden, a ban on the use of herbicides and the age-class structure of their forests have resulted in a large program of tending in young stands. In 1987, 350,000 ha were treated (Freij and Tosterud 1989a). Although the area requiring tending has been dropping, the annual program will remain around or above the 1987 level. The majority of the tending operations are plantation cleaning (i.e., cleaning birch [*Betula* spp.] out of a softwood plantation), but some precommercial thinning is also done.

Only 1% of the work was mechanized in 1987, but this should increase to 10% by 1992. Some recently introduced machines, the product of a development program during the 1980s, have made mechanized cleaning possible. The FMG 0450, Valmet 701 and Haglinge Jumbo cleaning machines have a number of unique features for cleaning applications. These include excellent visibility, long-reach parallelogram booms with precise joystick controls, and a high ground clearance that permits the machine to drive over a row of crop trees. An FMG 0450 was introduced to Nova Scotia in 1990, and is being used for both plantation cleaning and precommercial thinning (Fig. 4).

*Figure 4. FMG 0450 cleaning machine in operation in Nova Scotia.*

In Finland, approximately 260,000 ha of young stands are tended annually. Unlike in Sweden, herbicides are not banned. Mechanical techniques usually involve the use of brush saws, with or without spray attachments. Private owners doing the cleaning work themselves may use manual tools, such as brush hooks. There are currently no attempts to mechanize cleaning or precommercial thinning.

## Commercial Thinning

The importance of commercial thinning as a silvicultural treatment is well recognized in Europe. However, for a variety of reasons, not all countries have progressed in a similar manner in terms of mechanization. The situation in the Nordic countries, especially Finland and Sweden, is of particular interest to Canada. Dramatic changes in technology have occurred over the past 10 years, and some of this equipment has already begun to appear in our harvesting operations.

In 1985, 250,000 ha were thinned in Sweden. In a recent survey of harvesting techniques and trends on large-scale operations (> 20,000 $m^3$/yr), the annual cut from thinnings was 9.5 million $m^3$ and this was expected to rise to 12.0 million $m^3$ by 1992, which will then account for 27% of the total annual cut. Shortwood systems account for 94% of the total cut in Sweden. It should be noted that shortwood pulpwood lengths vary between 3 and 6 m and the amount of this random-length pulpwood will also increase by 50% by 1992 (Freij and Tosterud 1989b).

As shown in Figure 5, single-grip harvesters and motor-manual systems were the main methods used for thinning in 1987, accounting for 37 and 41% of the total, respectively. By 1992, the single-grip harvester method will dominate (63% of the thinnings) at the expense of the motor-manual system (down to 23%) and the limber-bucker (down to 5%). The degree of mechanization in thinning will increase from 47% in 1987 to an estimated 69% by 1992.

The introduction of the single-grip harvester has permitted this rapid increase in mechanization of thinning. Single-grip harvesters also accounted for 11% of the final felling in 1987 and this will increase to 26% by 1992 (Fig. 6).

Thinning is also a common practice in Finland, and up to three commercial thinnings may be done during the rotation, depending upon the latitude. Thinnings account for just less than 30% of the total annual cut, but the need for thinning in younger stands will increase because of the age-class distribution of their forests. The target is between 300,000 and 400,000 ha/year in the 1990s. Large areas of drained peatlands are also reaching the first thinning age, and there has been a challenge to produce thinning machinery capable of operating on soft ground.

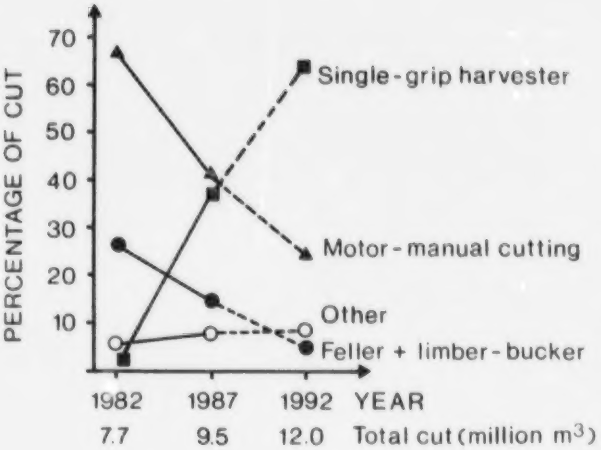


*Figure 5. Thinning systems in Sweden (from Freij and Tosterud 1989b).*

*Figure 6. Single-grip harvesters are used for both thinning and final felling in Scandinavia.*

Mechanization has not been as dramatic in Finland as in Sweden but it is expected to increase rapidly because of the foreseen increase in the area treated and the difficulty in attracting skilled labor to the forest. Gradual lengthening of pulp logs has also occurred, from 1 or 2 m to 3 or 5 m. Compared with 2-m lengths, the total cost (including harvesting and transportation) of 3- and 5-m-long pulpwood is decreased by 8 and 13%, respectively (Hakkila 1989).

## Equipment

The pattern of land ownership as well as other factors in Nordic countries have led to a variety of systems suitable for large- and small-scale operations and a wide range of stem sizes. The following is a brief review of the equipment and methods used primarily on large-scale operations.

Single-grip harvesters are used in early and subsequent thinnings. Harvester heads are available in various sizes, and the maximum stem diameter that they are capable of cutting ranges from 25 to 55 cm; the weight of the cutting head varies from 200 to 800 kg, respectively. In selecting a particular head, mean diameter of the stems to be removed, tree-diameter variations, branchiness and branch size, the proportion of hardwoods in the stand, and the number of residual stems after thinning should also be considered (Scherman 1986). There are no less than 50 makes and models of harvester heads in use in the Nordic countries.

The key components of a typical single-grip harvester head are as follows (Fig. 7):

- a chainsaw felling head that also performs the bucking;
- a rotator and tilt cylinders, which allow the tree to fall independently of the boom;
- the delimber feed (various rollers, chain drive, or stroke designs). Intermittent-stroke delimber-feed mechanisms, such as the Tapio, are slower (1 m/s as opposed to 3 m/s), but the delimbing force is much greater; and
- the bucking unit, comprised of length- (and in some cases, diameter-) measurement apparatus. Microprocessors, which optimize the value of the logs while bucking the stem and storing the scaling data, are also being used on some models.

Many of the harvesters are mounted on a 6- to 8-wheeled forwarder chassis. However, some of the newest one-grip harvesters are built on special base machines. Ergonomics were considered very important when building these machines and cab comfort, working position and visibility while thinning were stressed.

The extraction equipment consists of various makes and models of forwarders. In early thinnings, forwarders in the 7-tonne payload class are used. These small forwarders have been designed to work efficiently without damaging the stand or forest floor. Features include: narrow width; low weight and ground pressure, with exact tracking between front and rear wheels; good maneuverability; and good visibility in all directions. Forwarders used in subsequent thinnings are typically in the 10- tonne payload class, weigh 10 tonnes unloaded, and have a loader with a 10-m reach.

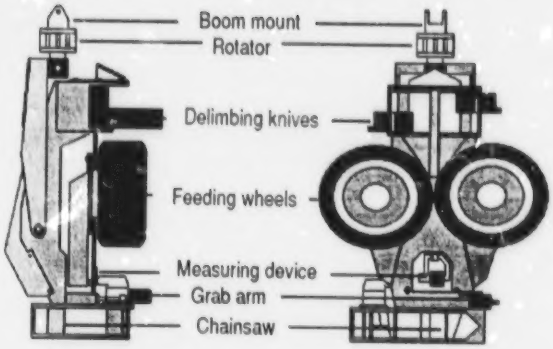


*Figure 7. A typical single-grip harvester head.*

Tracked machines with rubber or steel tracks are also being produced, primarily by Finnish manufacturers, for thinning in peatlands (Fig. 8). Some can be converted from a forwarder to a harvester in approximately one hour (e.g., the Nokka Joker).

*Figure 8. Small, tracked single-grip harvester (modified from Scherman [1986]).*

## Working Methods

Although all single-grip harvesters are basically similar, their application can vary. By Swedish law, no more than 20% of the thinning area can be comprised of strip roads. With a 4-m-wide strip road, the distance between roads must be at least 20 m. A 25- to 30-m distance is usually used when the strip roads have been planned in advance. Since the practical reach of a harvester's boom is usually less than 10 m, this creates an intermediate zone between the roads. Thus, around 20% of the stems must be felled motor-manually towards the strip road after the harvester has made its first pass. The harvester processes these trees during a second pass along the same strip road (see Fig. 9).

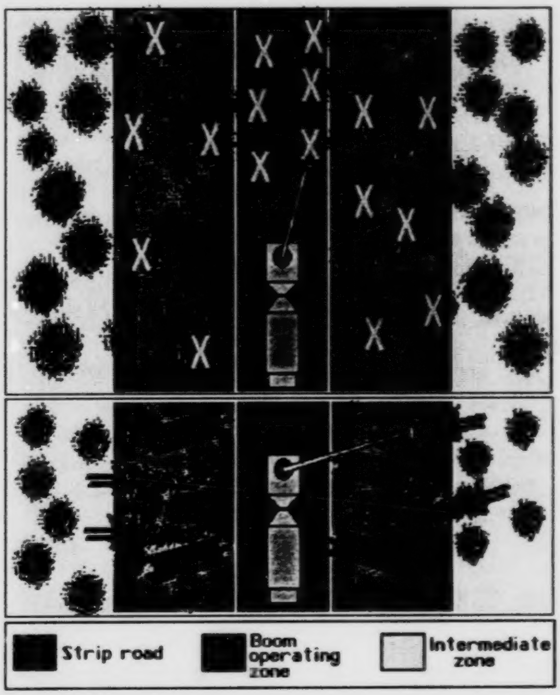


*Figure 9. Thinning with single-grip harvesters operating on strip roads is usually done in two passes in Sweden (from Scherman [1986]).*

Felling of the trees in these intermediate zones is carried out by the operator, but not with the machine. It is common for two or three operators to alternate between operating the machine and performing motor-manual work. Typically, a 12-hour shift is used. This system has a number of advantages:

- short (3-hour) operator turns on the machine;
- better coordination of machine operations and motor-manual work; and
- the operators can check their work while off the machine.

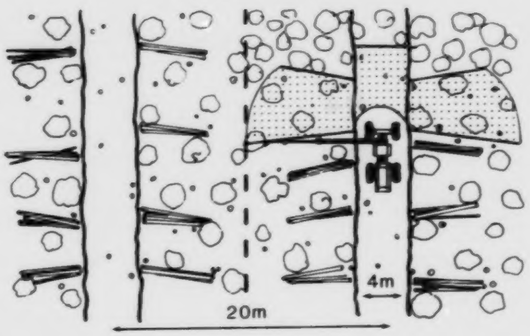
By law, damage to residual trees must be less than 5% (stems and roots), and the operators select the trees to be cut. With proper planning and execution, the single-grip harvester method can meet this target.

However, there have been efforts in Sweden to mechanize thinning fully and smaller, lighter machines, such as the FMG 0470 and Valmet 701, have been developed recently for this purpose.

Since the 20% rule does not apply in Finland, the strip roads are also closer together. Moreover, the small, tracked harvesters are allowed to enter the stand between the strip roads (Fig. 10).

Nevertheless, the small tree size and density encountered while thinning young stands restrict profitability. In general, an average tree size of at least 0.07 m$^3$/tree is required using the previously described methods. Therefore, a tree-section method has also been developed for first thinnings with a small tree size (Olsson 1985). This method accounts for less than 10% of the thinning in Sweden.

One-grip harvester



Small harvester

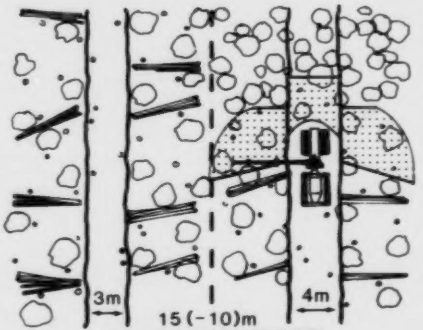


*Figure 10. Common thinning methods in Finland (from Anon. 1989).*

The system consists of a semi-mechanized method with motor-manual directional felling or a fully-mechanized method with a feller-buncher-skidder that fells and skids full trees to the strip road. A forwarder with a grapple saw mounted on a telescopic boom works along the strip road, cutting the trees in sections, usually in half. Tree sections are transported to the mill or a central processing facility for delimbing by a drum delimber. A short haul distance and a market for the biomass are required to make this method profitable.

## CONSTRAINTS ON TECHNOLOGY

### Precommercial Thinning

Canada is unique in that we rely heavily on natural regeneration techniques. As previously stated, a semi-mechanized system appears most promising, with a machine to cut corridors followed by a motor-manual operation to select the final crop trees. Potentially useful equipment from other countries is limited, other than some integrated brush-cutting machines from the United States. Most of the American equipment has been tried on a limited basis, but since it was made for other brush-cutting applications (right-of-way clearing, etc.), the width is usually excessive to match our desired or maximum tolerable strip width. Swedish cleaning machines are certainly potential candidates for trials, but there are many differences between cleaning a plantation and precommercial thinning in a natural stand. The suitability of these machines under Canadian conditions remains to be proven.

This situation creates an opportunity for us to develop a machine to match our own requirements. The current developments in Canada with various brush-cutting attachments (e.g., Usinaxe, Munger, TSS, Timberwolf, Weldco, etc.) demonstrate that we are already headed in that direction. Some of these may also have potential applications in precommercial thinning. However, since these are attachments, the challenge will be to optimize the match between the available prime movers and the brush-cutting attachment. Brush cutters mounted on excavators are presently being tried, but the experience to date is limited and training and experience will be of great importance in determining their success.

FERIC is currently trying to encourage a Canadian manufacturer to develop a wheeled prime mover for corridor thinning that can meet our needs in precommercial thinning. Target figures to demonstrate the potential amount of precommercial thinning to be done at this time or in the future are lacking. It is therefore difficult to predict the size of the market and to make a rational judgement on the amount of funds that can be spent on development. Fortunately, brush-cutting equipment can be used for other uses, and this enlarges the potential market.

Some of the operational constraints/problems that must be faced, based on the experience to date, include:

- the width of the cut strip;
- damage to the sides of the leave strip and to potential residual crop trees;
- low, live limbs and partially cut trees within the cut strip; and
- difficult ground and stand conditions.

These constraints are discussed in a report published by FERIC (Ryans 1988).

### Commercial Thinning

To date, the experience in Canada with mechanized commercial thinning is extremely limited. As in other countries, it will be much more difficult to mechanize thinning than final felling. Some constraints are: machine-size limitations, since freedom of movement in the handling of felled stems is limited by residual stems; strip-road width limitations versus boom reach and machine stability; the smaller tree size and high stand density; and the smaller volume of wood that must be used to recover the cost of the thinning.

Certainly, the technology from Nordic countries has potential application. In fact, this equipment has already begun to appear on clearcut operations in eastern Canada (Richardson 1988). The imported equipment includes both integrated harvesters (FMG Timberjack 990, Bruun 7620H, Valmet 901 and Rottne Snoken EGS-85) and heads mounted on excavators or wheeled carriers (Silvatec, Tufab, Tapio, Lako and Keto). Some of the experience with this equipment in clearcutting operations and the differences in stand conditions between Canada and Scandinavia can help us to foresee some potential problems in thinning applications.

One of the main differences will be between thinning in an unmanaged natural stand, as is the case for much of Canada, versus thinning in a plantation (Fig. 11). The lack of row integrity, a wider variation in species, density and diameters, and the amount of dead, unmerchantable stems will all hinder mechanized thinning and the effective use of one-grip harvesters. Canadian species tend not to be as straight and their branching habits differ from those of Scots Pine (*Pinus sylvestris* L.) and Norway Spruce (*Picea abies* [L.] Karst.) in Scandinavia. The problem is further aggravated by the fact that placing higher value on the final crop means removing all the trees with poor form (crooks, double tops, etc.).

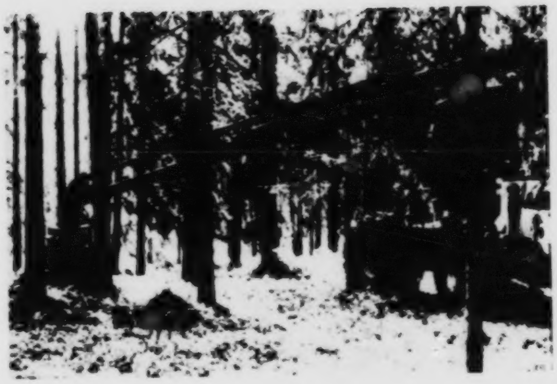


*Figure 11. A one-grip harvester thinning in a previously managed stand in Sweden. Note the excellent visibility.*

Underbrush is also a major concern. If there are visibility problems created by small unmerchantable trees in Sweden, an operator with a brush saw often cleans the stand ahead of the machine to make operation of the harvester profitable. Much more difficult brush conditions can be anticipated in our natural stands. Brush and poor visibility can result in problems with the exposed hoses and the chainsaw felling head. Clearing brush with a freely suspended harvester head is difficult, especially with a lighter thinning head.

Another problem is the high cost of foreign technology. A $400,000 to $500,000 single-grip harvester requires sufficient area and scheduled hours to make it pay. Proper training of mechanics, service and parts supply are other essential ingredients in a successful operation. Fortunately, most of the larger equipment manufacturers are taking steps to establish a dealer network. The purchase of a machine includes a training program for operators and mechanics. However, a forest worker in Scandinavia generally has had many courses in machine operation. In Finland, for example, a harvester operator must be an experienced forwarder operator and must then take further schooling (Vihola 1989).

Another potential constraint is the form of the wood taken to roadside. As previously mentioned, the trend in Nordic countries has been towards longer-length (3 to 6 m) and random-length pulpwood to rationalize mechanization, improve productivity, and increase fiber recovery. Many mills, mill yards, and handling and transportation systems in Canada are geared for a particular bolt length (2.52 or even 1.27 m), or for tree-length logs.

On the other hand, there are other opportunities for the application of some of this equipment:

- clearcutting applications: inherent advantages include leaving the limbs in the cutover rather than at roadside, and a mat of limbs is placed in front of the machine along the skid trail, which helps to reduce ground disturbance;
- modified harvest cutting: a one-grip harvester followed by a forwarder is a promising harvesting system to protect advance regeneration; and
- harvesting of buffer strips: to minimize the environmental impact.

## CONCLUSIONS

Over the past few years, there has been a surge in silvicultural activities and a dramatic increase in stand-tending practices. There are also indications of fiber shortages on the horizon in some regions.

Depending upon economic and labor factors, there is an opportunity to mechanize precommercial thinning operations at this time, and there are a number of ongoing developments. The experience in other countries indicates that commercial thinning can be made profitable with recent technology.

However, whether it involves the development of new equipment or the application of existing technology, a mechanized operation must ensure that the silvicultural objectives of the thinning are not compromised.

## LITERATURE CITED

Anon. 1989. Monitoimikoneopas. Metsateho, Helsinki, Finland. Metsatehon Opas. 13 p.

Forrester, P.D. 1989. Strip thinning with the Track-Ax in the East Kootenay Region of British Columbia. For. Eng. Res. Inst. Can., Vancouver, B.C. Tech. Note No. TN-130. 5 p.

Freij, J. and Tosterud, A. 1989a. Silviculture trends 1987-1992: large-scale systems and methods. Forsk. Skogs., Kista, Sweden. Results No. 4. 1989. 4 p.

Freij, J. and Tosterud, A. 1989b. Logging trends 1987–1992: large-scale systems and methods. Forsk. Skogs., Kista, Sweden. Results No. 3. 1989. 4 p.

Hakkila, P. 1989. Logging in Finland. Metsantutkimuslaitos, Helsinki, Finland. Acta For. Fenn. 207. 39 p.

Hedin, I.B. 1987. Strip thinning trials in British Columbia – 1986. For. Eng. Res. Inst. Can., Vancouver, B.C. Tech. Note No. TN-112. 16 p.

Hedin, I.B. 1990. Innovations in mechanized silviculture. p. 19–23 *in* Preprint book, 71st Annu. Meet., Woodlands Sect., Can. Pulp Pap. Assoc., Montreal, Que. 127 p.

Herring, L.J. 1981. Man vs. machine. B.C. Min. For., Prince George For. Reg., Prince George, B.C. Res. Rep. No. 3. 15 p.

Meyer, R.L. 1990. Slashbuster. Am. Pulp Paper Assoc., Washington, D.C. Tech. Rel. 90-R-71. 2 p.

Olsson, P. 1985. Tree-section logging in thinning. Forsk. Skogs., Kista, Sweden. Results No. 2. 1985. 4 p.

Richardson, R. 1988. An introduction to off-road processors and harvesters. For. Eng. Res. Inst. Can., Pointe Claire, Que. Tech. Note No. TN-126. 12 p.

Ryans, M. 1988. Mechanized precommercial thinning methods: experience to date. For. Eng. Res. Inst. Can., Pointe Claire, Que. Special Rep. No. SR-56. 17 p.

Scherman, S. 1986. Single-grip harvesters. Forsk. Skogs., Kista, Sweden. Results No. 2. 1986. 6 p.

Seymour, R.S., Ebeling, R.A. and Gadzik, C.G. 1984. Operational density control in spruce-fir stands — production of a mechanical swath cutter and brush-saw workers. Coop. For. Res. Unit, Univ. Maine, Orono. CFRU Res. Note No. 14. 26 p.

Sidders, D. 1989. Mechanical strip-thinning development trial, central Saskatchewan. Gov't of Can., Can. For. Serv., Prince Albert, Sask. Tech. Transfer Note S-004. 7 p.

Smith, C.R. 1987. Alternative methods for precommercial thinning of balsam fir: potential and requirements. p. 79–87 *in* Preprint book, 68th Annu. Meet., Woodlands Sect., Can. Pulp Pap. Assoc., Montreal, Que. 204 p.

St.-Amour, M. 1990. Precommercial thinning with a mini-excavator. For. Eng. Res. Inst. Can., Pointe Claire, Que. Field Note No. Silviculture-20. 2 p.

Vihola, T. 1989. Special training for advanced mechanization. p. 97–108 *in* Proc. joint FAO/ECE/ILO Comm. For. Working Tech. Training For. Workers Seminar, The Training of Professional Forest Workers, 22-26 May 1989. Helsinki, Finland. Finnish Gov't Printing Center, Helsinki. 262 p.

# TREE SIZE AND ITS EFFECT ON MACHINES AND PRODUCTIVITY

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## ABSTRACT

Tree size is the single most important factor affecting the productivity of forest harvesting machines. This paper examines the physical limitations of harvesting machines in relation to tree size and discusses the effect of decreasing tree size on machine productivity. Thinning places special demands on men and machines, but offers the opportunity to increase tree size in the next harvest cycle.

## RÉSUMÉ

La taille de l'arbre est le seul facteur déterminant qui se répercute sur la productivité des machines d'exploitation forestière en fonctien de la taille des arbres. Ce rapport examine les limites physiques des engins d'exploitation forestière en fonction de la taille des arbres et étudie l'effet de la réduction de la taille des arbres sur la productivité des engins. L'éclaircie impose des exigences spéciales sur les hommes et les machines, mais offre la possibilité d'augmenter la taille des arbres au cours du prochain cycle de récolte.

## INTRODUCTION

If we still had large trees across the country today, there would not be a need for a symposium to discuss spacing and thinning for the purpose of increasing tree size over a shorter period of time. Left as we are with small trees, it is imperative that we fully understand their impact on both the design and productivity of machines.

## EVOLUTION IN MACHINE DEVELOPMENT

We know that a worker with a chainsaw and a cable skidder can harvest large trees productively but that productivity decreases significantly as the trees get smaller. With smaller trees as the norm in our boreal forests, the cut-and-skid method of harvesting is no longer practical. Thus, declining tree size has become the driving force in changing logging methods and systems.

While the cut-and-skid method was widely practiced, manufacturers designed skidders capable of handling a wide range of stand, terrain and snow conditions. With mechanical felling came grapple skidders to pick up the bunched trees and skid them to the roadside. Once this capability was established, the driving force in machine evolution was the concern for operator safety as well as a means to offset the lack of available labor.

Timberjack, for example, manufactures a wide array of forestry machinery (Fig. 1). The product line includes feller bunchers, in both conventional and steep-slope configurations, to handle the different stand and site conditions from coast to coast. There are cable, grapple and clam-bunk skidders to move full-tree and tree-length wood from stump to landing. Two models of cut-to-length harvesters fell and process wood in the forest and there are forwarders of from 5 to 20 ton (4,536 to 18,144 kg) capacity to move the processed wood to the roadside. The harvesters not only operate in virgin stands, but have more recently been used effectively in stand-improvement work, thinning in plantations, and selective cutting in natural stands.

In current cut-to-length operations, two types of machines are commonly used: harvesters and forwarders. The harvester fells the tree, delimbs it and cuts it to length, producing sawlogs, pulpwood or both. The forwarder follows the harvester and transports the wood to the roadside and, in many cases, loads it directly onto waiting trucks. The wood stays clean. This is a very effective approach because there is little inventory to process at the mill, no landings are required, and the wood is ready for the mill. In many "hot-logging" operations, the contractor is paid by weight and, from his point of view, the greener the wood, the better.

## TREE SIZE VS. MACHINE PRODUCTIVITY

How does tree size affect the productivity of a cut-to-length harvester? Consider a typical natural stand and compare a tree that is 6 in. (15.2 cm) in diameter with one that is 12 in. (30.4 cm) in diameter. From Table 1 we can

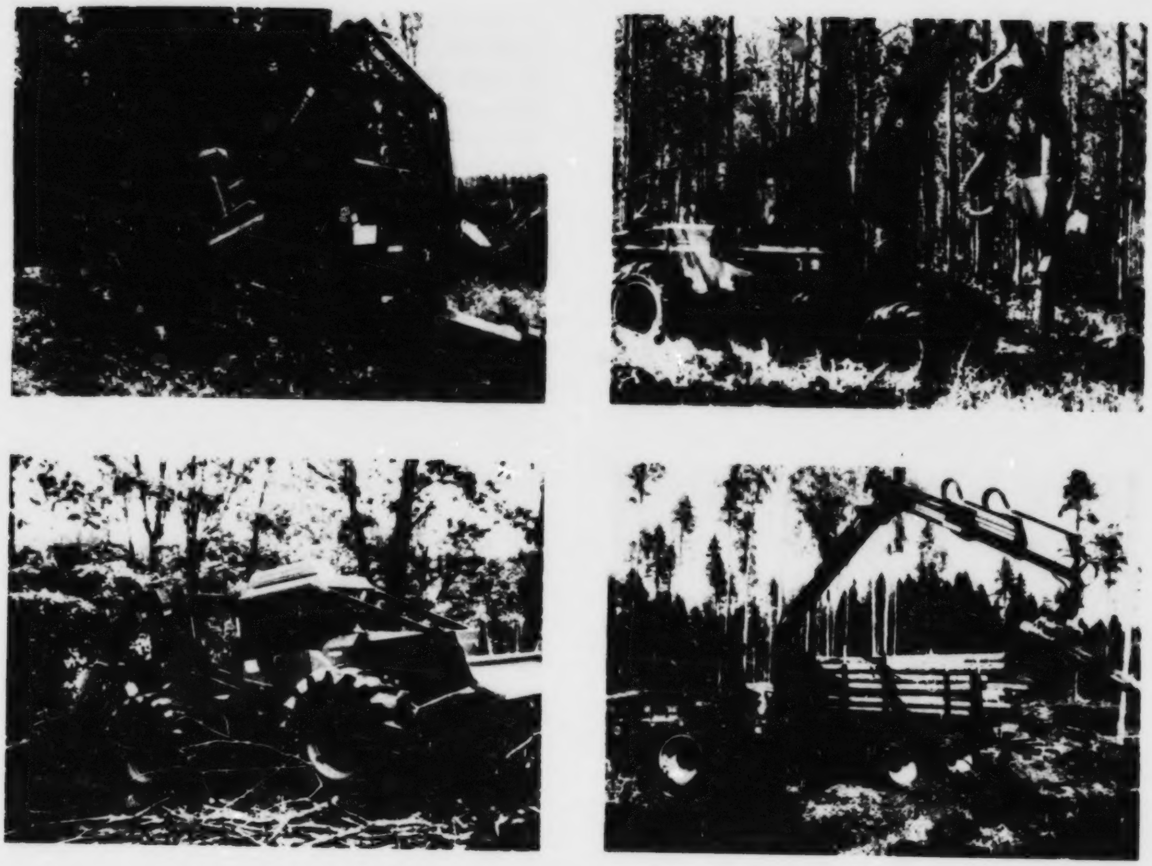

*Figure 1. Forestry machinery produced by Timberjack Inc. for use in harvesting: Feller-buncher (top left), skidder (bottom left), harvester (top right) and forwarder (bottom right).*

see that the full-tree weight of the smaller tree (for the example of white spruce, *Picea glauca* L.) is 293 lb (222 lb net) (133 and 100.8 kg, respectively); by comparison, the larger tree weighs 1,498 lb (1,161 lb net) (680.1 and 527.1 kg, respectively). Therefore, doubling the diameter of a tree increases its weight more than five-fold. When an operator cutting the smaller trees comes to a 20-in. (50.8 cm) tree, he should know that he will be handling a stem weighing 2.5 tons (2,268 kg) (see Table 1), the maximum capacity of the machine.

Size affects productivity greatly, especially when one considers that an operator must harvest 17 6-in. trees to produce the same amount of wood as a single 20-in. tree. Even working with great speed, there is simply no way that comparable volume productivity can be maintained from smaller timber.

A cut-to-length harvester can handle a range of tree sizes from 4 to 20 in. (10.2 to 50.8 cm), but what volume production should the operator expect in each size class? From Table 1, we can see that the stem weight of a 20-in. tree is *61 times heavier* than that of a 4-in. tree. Obviously, declining tree size has a major adverse effect on harvesting productivity, and the effect extends through scaling, handling and processing at the mill. As things stand, an operator cannot be very productive in an unmanaged forest unless some spacing and precommercial thinning has been done to remove some of the smaller trees so that the rest can grow to a more useful size more quickly.

## THE SUCCESSFUL LOGGING OPERATION

Three things are needed for a successful logging operation. First, the harvest must be *physically possible*. If a machine can get safely to the job, we can fit it to the application by providing high-flotation tires, flexible-tracks, chains, or whatever is needed. The harvesting head will be selected according to tree size. Next, we must ask if the harvest is *economically feasible*. Can a sufficient number of trees be cut and processed to cover the fixed costs, operating costs and any other variable

Table 1. Comparison of green weights of stems and full trees of white spruce in Maine over a range of diameters.[a]

| DBH (in.) | Green weight (lb) Stem | Full tree |
|---|---|---|
| 4 | 64 | 113.2 |
| 5 | 144 | 192.2 |
| 6 | 222 | 293 |
| 7 | 321 | 422 |
| 8 | 441 | 577 |
| 9 | 584 | 761 |
| 10 | 751 | 975 |
| 11 | 943 | 1220 |
| 12 | 1161 | 1498 |
| 13 | 1405 | 1808 |
| 14 | 1677 | 2152 |
| 15 | 1977 | 2531 |
| 16 | 2306 | 2945 |
| 17 | 2665 | 3397 |
| 18 | 3054 | 3886 |
| 19 | 3475 | 4414 |
| 20 | 3927 | 4980 |
| 21 | 4412 | 5586 |
| 22 | 4930 | 6232 |
| 23 | 5482 | 6922 |
| 24 | 6068 | 7651 |
| 25 | 6689 | 8423 |
| 26 | 7345 | 9238 |

[a] Data in the text that have been excerpted from this table have been converted into metric form by the editors.

costs that might occur? The owner of the machine must be able to make a profit commensurate with the effort and cost invested. Finally, the operation must be *socially and environmentally acceptable* to ourselves and to the public. Rutting of the forest floor is no longer accepted, and this can be minimized with high-flotation tires. There is a growing resistance to road construction from the points of view of cost, the impact of sedimentation in our waterways, and the effect on wildlife. Longer forwarding distances can significantly reduce road density, though, of course, the logger must be compensated for the longer haul distances.

The social and environmental considerations of forest harvesting in the 1990s will focus on air quality, water quality, ground disturbance, stand management (the focus of this conference), the effect on wildlife, aesthetics, recreational demands, preservation of old-growth forests, and road/landing densities. The truth of the matter is that the public's view of what a forest is supposed to look like after a harvest is what equipment manufacturers and forest managers must try to achieve.

For our part, we believe that a solution lies in the cut-to-length method of harvesting, which has evolved in Scandinavia in response to many years of strong social and environmental pressures. There will be difficulties in applying these machines to our natural, unmanaged, small-dimension forests, but there is a future for such machines. Consider a forest of 6-in. (15.2-cm) trees spaced at a young age: if one waits until they are 8 in. (20.3 cm) in diameter, the weight of the stems doubles (Table 1). This clearly demonstrates the current opportunity for spacing and thinning. Thinning operations can be done correctly using appropriate silvicultural principles. If done mechanically, branches and tops will be distributed over the forest floor to prevent or at least minimize root damage that might otherwise occur during felling and extraction.

## CONCLUSIONS

At this conference, and in most forestry studies, the focus has been almost exclusively on DBH — tree diameter at breast height. However, harvesting companies are paid by volume, not diameter. We must focus on the value of a tree as it grows in *diameter* and *volume*: the bigger the tree, the more options we have.

As equipment manufacturers, we attempt every day to help our customers solve some of the problems they face in terms of declining tree size in unmanaged forests. We can show that mechanical harvesting can be done without seriously altering or damaging the environment, but this harvesting becomes less economically feasible as tree size declines.

Commercial thinning reaps dividends, and we can demonstrate that it can be done mechanically. As examples, Figure 2 shows the pulpwood and sawlog yields resulting from clearcutting 40 ac (16.2 ha) of typical 70-year-old natural red pine (*Pinus resinosa* Ait.) by the Potlatch Corporation in the Lake States. This unmanaged forest yields a total of 872 cunits (2467.8 $m^3$) of merchantable wood (21.8 cunits/acre) (152.4 $m^3$/ha), comprising 392 cunits (1109.4 $m^3$) of pulpwood and 288,000 board-feet (approximately 672 $m^3$) of lumber. On the other hand, the same area of planted red pine (Fig. 2), harvested at the same age but after thinning at 40, 50 and 60 years, yields almost three times as much volume. Thinning has not only produced intermediate returns, but has enhanced the growth of the remaining stems to produce only 61% as much pulpwood, but almost 500% as much lumber. The total yield after three thinnings and a final felling is 2.75 times the wood produced from a single clearcut at 70 years. Of even greater significance is that if a mill relied only on clearcut harvesting, 110 ac (44.4 ha) of unmanaged natural

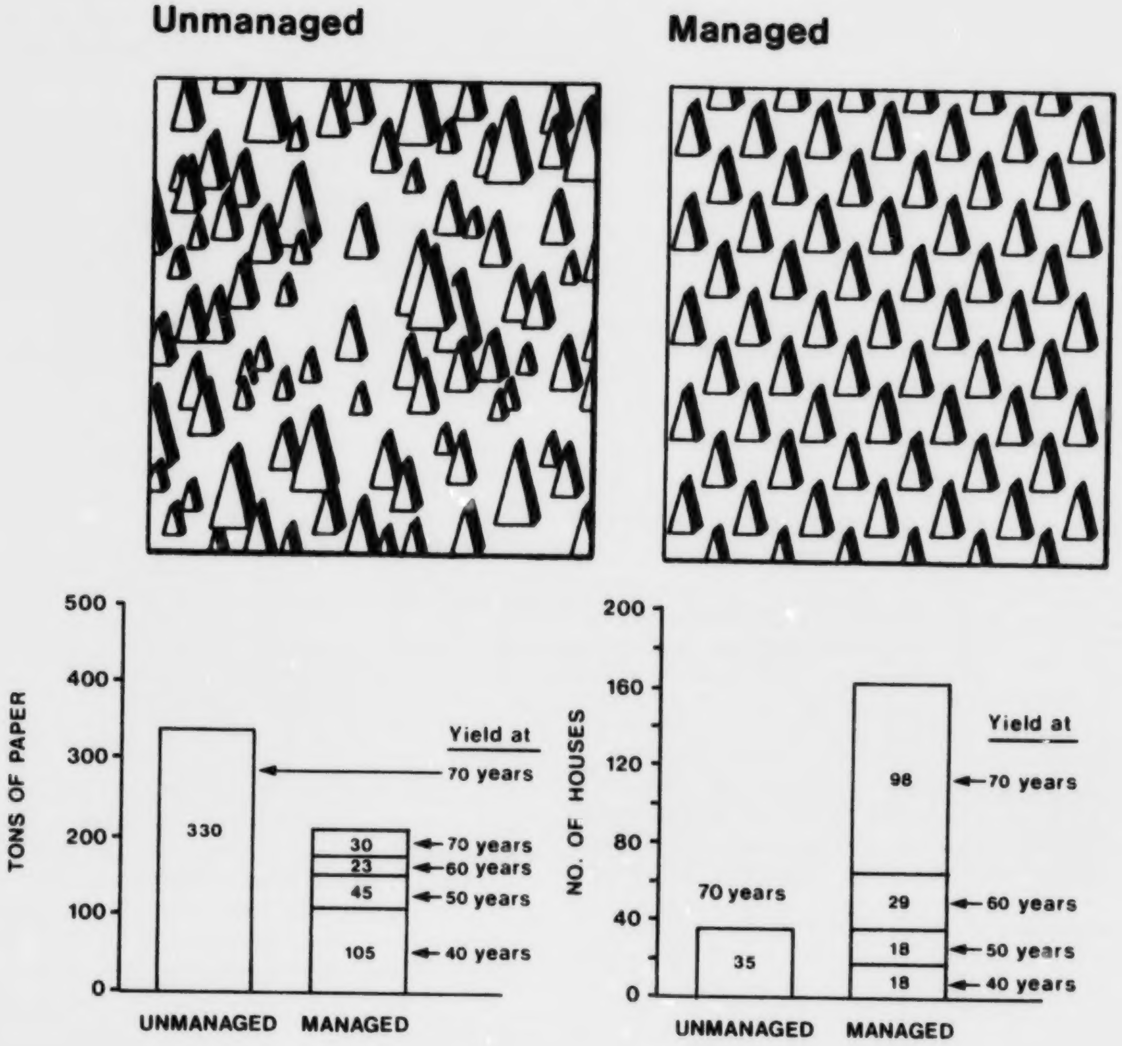

*Figure 2. (Left) The expected yields from harvesting 40 ac of 70-year-old red pine. (Right) The expected yield from harvesting the same stand; but with thinnings conducted at 40, 50 and 60 years.*

forest would have to be cut to yield the same volume of wood produced after thinning and harvesting 40 ac. These are the numbers we must be concerned with.

Spacing and thinning have a major role in forest management and, if implemented today, we would not only have timber for harvesting when the wood-supply "gap" is projected to occur, but also harvesting and processing equipment that would operate more economically as a result of the larger material: tree size has been the driving force in machine design and evolution, but *declining* tree size has been the driving force in changing logging methods and systems.

# SPACING AND THINNING IN MANITOBA

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## ABSTRACT

Jack pine (*Pinus banksiana* Lamb.) thinning research has been carried out in Manitoba since the early 1900s. Since that time, operational thinning projects have been conducted periodically in fire-origin and artificially regenerated jack pine forest stands.

A summary is presented of the history, methods and effectiveness of jack pine thinning in Manitoba and reference is made to manual stand improvement cuttings involving other tree species. The current status and future employment of these programs by provincial and industrial agencies is also discussed.

## RÉSUMÉ

Depuis le début des années 1900, des recherches sur les éclaircies dans les peuplements de pins gris (*Pinus bankskiana* Lamb.) sont menées au Manitoba. Depuis cette époque, de véritables coupes d'éclaircie ont été périodiquement effectuées dans des peuplements de pins gris nés à la suite d'un incendie et issus d'une régénération artificielle.

L'auteur résume l'historique, les méthodes et l'efficacité des éclaircies des peuplements de pins gris au Manitoba et aborde le sujet de coupes d'amélioration manuelles dans des peuplements d'autres espèces d'arbres. Il examine également l'état actuel et l'utilisation future de ces programmes par les organismes provinciaux et l'industrie.

## MANITOBA'S FORESTS

The total land area of Manitoba is approximately 550,000 km$^2$. The province of Manitoba is 51% forested, and half of this is designated as productive forest land owned by the Crown. The productive forest of Manitoba is primarily in the Boreal Forest Region, with a small portion in the Great Lakes – St. Lawrence Region in southeastern Manitoba (Rowe 1972).

The major tree species in Manitoba are black spruce (*Picea mariana* [Mill.] B.S.P.), trembling aspen (*Populus tremuloides* Michx.) and jack pine (*Pinus banksiana* Lamb.). These species comprise 81% of the volume of growing stock (Samoil 1987). From a knowledge of the silvics of these three boreal species, one can appreciate the opportunity that exists in Manitoba for stand-tending projects such as thinning, spacing and release.

In our province, the annual area harvested is approximately 11,000 ha. Our two major forestry companies are Abitibi-Price Inc. and Repap Manitoba Inc. Abitibi-Price, established in 1928, is the oldest forest products company in the Prairie Provinces. The company's newsprint mill is located in Pine Falls, on the Winnipeg River. Repap, formerly Manfor Inc. and Churchill Forest Industries, currently produces unbleached kraft paper but is expected to begin producing pulp for clay-coated paper. More than 90% of the roundwood harvest is spruce and pine, three-quarters of which is used as pulpwood (Steele and Williamson 1985). The forest industry is Manitoba's fifth largest industry in terms of salaries and wages.

There is currently a surplus of softwoods in Manitoba, primarily in remote areas of the province. A hardwood surplus exists throughout the province; however, a trend towards increased utilization of hardwoods has been observed in recent years (Anon. 1986).

As in all provinces with boreal forests, Manitoba has a history of forest fires. Fires in the southeastern, eastern and western regions of Manitoba in the 1950s and 1960s provided much of the earlier thinning areas. In the 1980s, fires occurred in practically every region of the province and will provide future thinning opportunities. The only area spared from these fires was the southeastern region, which is more established, has better road access and which is, therefore, better protected. The 1989 fire season brought our province international attention when more than 3 million ha were burned.

## SILVICULTURE

Artificial regeneration has been carried out in Manitoba since the early 1900s. Most of the early work was in the Mountain and Sandilands forest sections of the province.

In 1981, Manitoba planted 3.5 million seedlings, mostly by provincial agencies. Currently, Manitoba plants 16 million seedlings, more than half by provincial agencies and the balance planted by Abitibi-Price and Repap. Hadashville and The Pas are the homes of the two provincial nurseries. These provincial nurseries produce all the stock that is planted in Manitoba.

Manitoba conducts operational planting of black spruce, jack pine, white spruce (*Picea glauca* [Moench] Voss) and red pine (*Pinus resinosa* Ait.). We also perform site preparation, scarification for natural regeneration, direct seeding, insect and disease control treatments, and chemical and manual stand tending.

### Stand Tending

The Province of Manitoba's Forestry Branch has conducted operational thinning projects for some time, but has shown greater interest in this practice since the 1960s. In the last 5 years, the province has tended more than 6,000 ha; 60% of this work was performed by government and 40% by the forest industry.

The benefits of stand tending include an increased volume of merchantable wood; increased value of roundwood harvests, including sawlogs, Hydro poles, etc.; early returns from commercial thinning and lower final harvest costs; an improved proportion of favored species; shortened rotation ages; less wood waste to interfere with silvicultural efforts; increased wildlife use through improved cover and vegetative browse; increased public use, including cross-country skiing, hiking and hunting; improved aesthetics; and, eventually, reduction of fire risks.

Over the years, the stand-tending workforce has included conscientious objectors, seasonal firefighters, forestry staff, silvicultural crews, participants in rehabilitation programs and private contractors. The tools employed include axes, saws, brush hooks, chainsaws, brush saws and row-thinning machinery. Work is carried out primarily in pure juvenile forest stands of fire origin; however, manual release/spacing of black spruce, white spruce and red pine also occurs in mixedwood forest stands of natural or artificial origin.

It is interesting to hear all the different terms being used at this conference to describe stand-tending treatments. In Manitoba, we refer to "spacing" when treatment involves more than one species of tree at a juvenile age; "thinning" involves trees of the same species at precommercial or commercial sizes; and "release" is the removal of undesirable tree species that have achieved dominance over a crop tree.

### Jack Pine Thinning

Thinning of jack pine has been conducted in all regions of the province. The earliest work was done in fire-origin jack pine. In the 1960s we did some mechanical and strip thinning in the northern Region[1]. During the 1970s and 1980s, precommercial thinning of natural jack pine was done throughout the province. In the mid-1980s, a limited program that combined jack pine thinning with pruning and mistletoe removal was attempted. For the most part, operational thinning projects were not based on the application of a crop plan. Selective-thinning instructions incorporated such factors as the removal/control of gall rust (*Endocronartium* sp.) in the western region, and thinning from below to favor dominant and codominant crop trees.

### Red Pine Thinning and Pruning

Tending of red pine has included removal of "volunteer" jack pine from red pine plantations, selective thinning, systematic row thinning and pruning. Selective thinning has been done to extract the commercially thinned material for pulpwood. Tree selection is normally done by the thinning crew, but trees may be marked by forestry staff in older plantations.

Some of the older red pine plantations have been heavily thinned and pruned in preparation for their use as seed production areas. An area in the southeastern region has been designated as a refuge for fur-bearing animals in order to protect the squirrel population. Cone pickers annually raid squirrel caches of red pine cones.

### Release of White Spruce from Aspen Competition

In 1984, white spruce planted in 1967 was released from trembling aspen competition with brush saws. Silvicultural crews were trained, in part, by a Husqvarna training specialist. Measurements taken in 1988 indicated that aspen suckering was less vigorous because of the timing of the release in spring and early summer; there was no significant difference in spruce height growth, crown density was greater as a result of increased sunlight, susceptibility to frost damage narrowed the crown somewhat, and the volume growth of released white spruce was significantly greater than that of unreleased white spruce (Delaney 1988).

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[1] D.F. Stewart, 1964. Northwest region thinning project NW-63-1. Manitoba Dep. Nat. Resour., Winnipeg, Man. Unpubl. Rep. 2 p.

In 1986, Johnson Forestry Service conducted a literature review (Johnson 1986) of information available in Canada on the release of white spruce from trembling aspen as part of the Canada–Manitoba Forest Resource Development Agreement (CMFRDA).

### Abitibi-Price Inc.

Abitibi-Price, located in Pine Falls, has thinned a total of 900 ha, 800 ha of black spruce and 100 ha of jack pine. Abitibi-Price performed the black spruce spacing on lowland sites of generally lower productivity close to the mill. Their intention was to decrease gross volume per hectare but increase merchantable volume per hectare by thinning to 3,000 stems/ha.

A 5-year analysis of thinned and unthinned black spruce in this area showed there was no significant difference in height growth but that volume production was 3.5 times greater on the thinned site. It is estimated that it will be 20 years before a spacing factor[2] of 18% is reached (Anon. 1990).

### Repap Manitoba Inc.

Repap, located in The Pas, has spaced a total of 1,144 ha, 150 ha in 1984 and 994 ha as part of the CMFRDA between 1984 and 1988. Spacing was conducted as follows: deciduous species were removed and softwoods were spaced to 1.8 m; preferred trees were white spruce, followed by jack pine, black spruce and trembling aspen; crop-tree selection was based on form, growth, and incidence of injury and disease, with preference given to dominant and codominant trees.

A jack pine spacing trial performed in August 1972 thinned 12-year-old jack pine, 3.4 m tall, to spacings of 2.4 x 2.4 m and 3.0 x 3.0 m. The best diameter growth and form were found at the 2.4- x 2.4-m spacing. At the 3.0- x 3.0-m spacing, the trees had poor form (crooked and forked) and lower height growth[3].

A spacing trial was established in 1987 to release jack pine from aspen competition. Spacings were 1 x 1 m, 2 x 2 m, and 3 x 3 m.

### Forestry Canada

Forestry Canada (previously the Canadian Forestry Service) researchers recognized the potential for stand tending in Manitoba and have conducted thinning research studies for some time. By 1970, there were 18 projects involving jack pine, trembling aspen and the spruces. Most of the research activity has occurred in the Mountain and Sandilands forest sections of the province. The oldest project I could find is a 1921 jack pine thinning study in western Manitoba (Cayford 1964).

A review of silvicultural research on jack pine by the federal government (Cayford et al. 1965) found that, in Manitoba:

- diameter growth increased after thinning;
- generally, the heavier the thinning, the greater the diameter growth;
- generally, thinning did not increase height growth;
- after heavy thinning, height growth was actually reduced;
- generally, thinning produced less gross volume;
- in one study, light thinning produced more volume;
- the 40-year results of thinning 10-year-old jack pine to 1.82-m spacing were that merchantable volume increased by 1,200 board-feet/acre (approximately 7 $m^3$/ha) or 198 poles/ha.

From the results of these studies, it was recommended that one heavy thinning be performed at a young age or thinning from below should be done as soon as the trees are of merchantable size.

## OPERATIONAL HAZARDS

Though we are aware of the benefits of stand tending, we must also be aware of the operational hazards. These include: physical crop damage while tending (breakage from falling stems and accidental cutting of stems); the potential for snow-loading damage and windthrow (black spruce and pine); increased wildlife damage (browsing by rabbits and porcupines and stem rubbing by deer); increased spread of and susceptibility to damaging insects and diseases, especially western gall rust of jack pine; and increased initial fire hazard and frost damage.

## THE FUTURE

What place will thinning and other manual stand-tending practices have in the silvicultural operations in Manitoba? There will always be a supply of dense, fire-origin jack pine stands that would be candidates for thinning (an average of 158,000 ha/yr; more than 3 million ha in 1989). The risk of losing the thinning work to subsequent fires may result in the concentration of thinning efforts in areas that are easier to protect. These areas would be "behind the mill", where economic returns could be maximized, or in areas where other resource interests (tourism, etc.) would increase the protection priority.

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[2] spacing factor = (square root of [unit area/stems per unit area] – stem height) x 100%

[3] D. Hunt. 1982. Measurements of the jack pine thinning trials on Cowan Bay (1981). Manitoba For. Resour. Ltd., The Pas, Man. Unpubl. Rep

A greater portion of stand-tending work would be in artificially regenerated stands in which an investment has already been made (e.g., jack pine and red pine), especially in the southeastern and eastern regions, where wildfire is more likely to be controlled.

Releasing softwoods from aspen competition, which is detrimental to softwood survival and growth, will continue. As we reforest productive mixedwood sites, it is more than apparent that we will encounter a competition problem. The results of regeneration surveys show that many softwood sites are regenerating to mixedwood cover types.

Manual stand tending will be conducted in areas where chemical release at an early age has not been performed or where manual release at a later age is the preferred option.

The benefits of thinning in terms of increased growth are clear. The question more foresters in our province have is whether this investment produces an economic return. More research needs to be done in this area. We also need more information on crop planning for our softwood species that takes into account regeneration dynamics.

Until the economic benefits of stand tending are proven, companies will be unlikely to entertain large-scale programs without financial assistance. However, it is anticipated that the forest industry will perform a greater portion of the provincial tending activities in the future. Stand-tending projects will still be done to preserve the softwood crop and when more than one objective, such as employment, wildlife management, forest protection or other considerations can be achieved.

## CONCLUSION

I recall an article I read some time ago about the characteristics of foresters. Generally, we are professionals with great faith. Sometimes our faith is shaken by things like the fire year of 1989 or, perhaps, by failures in plantation establishment. In order for us to improve the forest, we must recognize that thinning *is* a good practice and have faith that it will provide a return.

## LITERATURE CITED

Anon. 1986. Five year report on the status of forestry. Manitoba Dep. Nat. Resour., For. Br., Winnipeg, Man. 40 p.

Anon. 1990. The effects of a non-commercial thinning treatment on the growth and yield of 25 year old black spruce. Silvitech Consulting, Winnipeg, Man. 15 p.

Cayford, J.H. 1964. Results of a 1921 jack pine thinning in western Manitoba. Dep. For., Ottawa, Ont. Publ. No. 1077. 8 p.

Cayford, J.H., Chrosciewics, Z. and Sims, H.P. 1965. A review of silviculture research in jack pine. Dep. For., Ottawa, Ont. Rep. 65-MS-2. 244 p.

Delaney, J.R. 1988. Four year response of white spruce after release from a poplar overstory in the Agassiz Provincial Forest — Manitoba. Lakehead University, Thunder Bay, Ont. B.Sc.F. thesis. 42 p.

Johnson, H.J. 1986. The release of white spruce from trembling aspen overstorys. A review of available information and silvicultural guidelines. Manitoba Dep. Nat. Resour., Winnipeg, Man. 109 p.

Rowe, J.S., 1972. Forest regions of Canada. Dep. Environ., Can. For. Serv., Ottawa, Ont. Publ. 1300. 172 p.

Samoil, J.K., *Ed.* 1987. Manitoba's forests. Gov't of Can., Can. For. Serv., Edmonton, Alta. For. Rep. No. 32. 16 p.

Steele, T.W. and Williamson, T.B. 1985. Manitoba's forest industry — 1985. Canada–Manitoba For. Econ. and Reg. Devel. Agreement. Manitoba Dep. Nat. Resour., Winnipeg, Man. 55 p.

# EXPERIENCES WITH JUVENILE SPACING OF JACK PINE IN ONTARIO

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## ABSTRACT

This paper describes some of the contractual aspects for arranging precommercial thinning (spacing) projects. The experience of thinning 4,100 ha in the Dryden District of Northwestern Ontario between 1985 and 1987, at an average cost of $298/ha, is used as the basis for the discussion. The wording of tenders and the importance of keeping this wording simple are described because of the influence of these two factors on the range of prices. One important conclusion of the paper is that a large amount of work can be accomplished by several small contractors at low cost with roughly the same administration and auditing requirements as for a few large contractors.

## RÉSUMÉ

L'auteur décrit certains des aspects contractuels des travaux d'éclaircie précommerciale. Les antécédents des coupes d'éclaircie qui ont porté sur 4 100 ha du district de Dryden, dans le nord-ouest de l'Ontario, entre 1985 et 1987, au coût moyen de 298 $/ha, servent de fondement à la discussion. Le libellé des soumissions et l'importance de la simplicité de ce libellé son décrits en raison de leur influence sur l'échelle des prix. Une conclusion importante de l'auteur est que l'on peut faire effecteur des travaux importants par plusieurs petits entrepreneurs, à peu de frais, avec, en gros, les même exigences d'administration et de vérification que si l'on faisait appel à un petit nombre de gros entrepreneurs.

## INTRODUCTION

Precommercial thinning began on an operational basis in Dryden District in 1985. During a 3-year period from 1985 to 1987, a total of 4,155 ha were thinned at an average cost of $298/ha. Densities varied from 7,000 to 14,000 stems/ha; the majority of the regeneration was 9 to 10 years old and 1.5 to 2.0 m tall.

## HISTORY

In northwestern Ontario, approximately 80% of our regeneration effort relates to scarification and seeding of jack pine (*Pinus banksiana* Lamb). Normal weather patterns in this area of the province produce hot, dry summers conducive to germination of jack pine. This method of regeneration is relatively inexpensive when compared with growing, planting and tending bareroot or container stock. When compared with shelter-cone seeding, the cost of the cones alone would exceed the total cost of the seed and its aerial application.

This type of natural regeneration in northwestern Ontario has one drawback; it invariably produces high stand densities. Growth stagnation as a result of high stand density results in a requirement for longer rotation periods to produce satisfactory merchantable volumes.

Dryden is a small northern community with a labor force typical of many areas of northern Ontario. In 1986, 2,507 ha of precommercial thinning was completed in this District at an average cost of $303/ha. The objective of this paper is to provide an overview of how this program was accomplished.

## PROJECT SELECTION

Projects were initially selected using a combination of local knowledge and air and ground surveys. Additional surveys were carried out on all sites that appeared to possess densities in excess of 6,500 stems/ha with an average minimum height of 1.5 m. The purpose of these surveys was to provide specific information about the individual project location. This information included stand density, height, average diameter, soil condition, access, etc. The importance of acquiring this information cannot be overemphasized. As a general rule, detailed, accurate information will result in more competitive bids and subsequently lower costs.

## CONTRACTS

The contract used to control this activity was obtained from Thunder Bay District in 1984 and modified to meet Ontario Ministry of Natural Resources (OMNR) contractual and silvicultural objectives. The contract is easy to read and understand and provides adequate protection to ensure the objectives are achieved. Because of its simplicity, individuals who have never considered bidding on a typical government tender often participate actively. The qualifications and financial requirements are in relation to the size of the project. As an example, on projects of less than 30 ha, only minimal experience in brush operations is required. This contract requirement is designed to encourage maximum competition.

In 1986, 51 projects were awarded to 33 contractors, with projects varying in size from 8 to 125 ha. Two tenders were released. The first tender, in June, was timed to coincide with the completion of tree planting, and represented 669 ha and 17 individual projects. The second tender, released in September to coincide with the normal lay-off of silvicultural workers, fire crewmen, etc., represented 1,439 ha, comprising 34 projects and 30 contractors. In addition, crews supervised by OMNR treated 399 ha; 76 ha had a bonus provision included in the contract.

## EQUIPMENT

A variety of equipment was used, with the majority of contractors selecting the large brush-clearing saws. A few contractors, primarily those normally employed in harvest operations, favored medium-sized chainsaws. OMNR crews used a combination of sandviks and brush saws; the saws were used in areas of high stand density or large bole diameter.

## PRESCRIPTION OBJECTIVES

The objective of this treatment was to reduce the density of young ($\leq$ 10 years) jack pine to between 2,600 and 2,800 stems/ha. Over the next 10-year period, a further reduction of 20% appears to be normal; this is a result of mechanical injury during the thinning operations and losses to insects and disease. In northwestern Ontario, when stocking densities of young jack pine are abruptly reduced below 2,000 stems/ha, the potential for windthrow or damage as a result of snow loading increases dramatically. To date, we have had no significant losses but have observed projects in which these losses have occurred. For this reason, new prescriptions specify higher stocking densities than those prescribed in other parts of Canada. Extensive areas of regeneration generally produce a mix of merchantable species and the contract is written to accomodate this scenario. As an example, where poplar (*Populus* spp.) is the only species present, the contract specifies spacing to a density of 1,100 stems/ha (3 x 3 m).

## PRODUCTIVITY

Tree height, bole diameter, density and access to the stand all have impacts on productivity. The smaller contractors (one- to three-person operations) had the highest productivity. This productivity can be related directly to project selection, familiarization with and maintenance of equipment, and monetary rewards. The majority of the smaller contractors averaged 0.75 to 0.8 ha/person-day.

## PERFORMANCE AUDITING

Under the terms of the contract, all operations were inspected weekly. The audit process included monitoring of crop-tree selection. The contract specified the characteristics of these trees, including dominance, form, absence of injury or disease, and spacing. The frequency of auditing larger contractors (15- to 25-person operations) was directly related to work quality and/or productivity. Auditors were assigned to contractors on the basis of their experience, the size of the operation, the proximity to other unit work, and so on.

## PRESENT SITUATION

In August 1990, an additional 490 ha of jack pine stands were tendered for thinning in Dryden District. The tender consisted of 11 projects; five contractors completed the work. The age, height and stocking densities were similar to those noted in the introduction. The average cost of the 11 projects was $338/ha.

There is sufficient regeneration in Dryden District requiring precommercial thinning to maintain a program of 1,500 to 1,800 ha/year for the next 5 to 7 years; thereafter, 1,000 to 1,200 ha/year can be sustained. If areas originating after wildfires were included, this figure would double.

## SUMMARY

The purpose of this presentation was to provide information on the planning, implementation and control of a large thinning program. Competition for each project must be encouraged or the costs may become prohibitive.

What do we expect to gain from this work? Other speakers at this conference are more knowledgeable and able to answer that question, but if you ask me, I'm betting we will reduce rotation ages by 25 years.

# OPERATIONAL CONSIDERATIONS FOR PRECOMMERCIAL THINNING

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## ABSTRACT

Efficient and cost-effective precommercial thinning operations depend on proper planning, organization, training, selection of saws and equipment, and quality control. Where choices can be made, maximum return (maximum fiber per dollar) will be realized on sites of higher quality in lower density classes. A stand height of 2 to 3 m is ideal from both biological and operational points of view. The organizational setup required for job efficiency and control depends largely on the size of the operation. Treatment specifications and standards and a suitable quality-control system should be well defined and understood. There is no aspect of precommercial thinning operations more important than training, which has a major impact on cost, quality and safety. It is critical that this training be done by qualified people, particularly for the operation of brush saws. Incentive systems are important in any labor-intensive operations. For precommercial thinning, it is necessary to know the relationship between stand density (and other ground factors) and productivity.

## RÉSUMÉ

Les éléments essentiels à des opérations d'éclaircie précommerciale efficaces et rentables sont une planification, une organisation et une formation appropriées, un choix judicieux de scies et d'équipements et un programme adéquat du contrôle de la qualité. Quand les circonstances le permettent, on peut obtenir un rendement optimal (production maximale de fibres ligneuses par dollar) dans les peuplements de meilleure qualité classés dans des catégories de plus faible densité. Une hauteur dominante de 2 à 3 mètres est idéale tant sur le plan biologique que sur le plan opérationnel. Le degré d'organisation requis pour veiller à l'efficacité et à un bon contrôle des travaux dépend, dans une large mesure, de la taille de l'exploitation. Les instructions et les normes de traitement et un système approprié de contrôle de qualité doivent être bien définis et compris de tous. Aucune étape des opérations d'éclaircie précommerciale revêt plus d'importance que la formation, qui a des répercussions majeures sur les coûts, la qualité et la sécurité. Il est crucial que cette formation soit donnée par des personnes compétentes, particulièrement en ce qui a trait au fonctionnement des scies à broussailles. Pour toute opération exigeant un important apport de main-d'œuvre, des programmes d'incitations sont nécessaires. Pour ce qui est des opérations d'éclaircie précommerciale, il faut déterminer le rapport entre la densité de peuplement (et autres facteurs liés au sol) et la productivité.

## BACKGROUND

Corner Brook Pulp and Paper has had an operational precommercial thinning (PCT) program since 1976. Up until 1980, the program was modest (approximately 500 ha/year), but in 1981, with the advent of government cost-sharing agreements (e.g., the Forest Resource Development Agreement), the program expanded to 2,500 ha/year. In 1989, 3,000 ha were treated and the plans for 1990 are for 3,600 ha. Precommercial thinning has always been the major thrust of the company's silviculture program, with some 25,000 ha treated to date. The company currently employs 150 PCT workers from early June to late September (80 to 90 working days per year). Treated areas are predominantly balsam fir (*Abies balsamea* [L.] Mill.) with average densities in excess of 50,000 stems/ha.

As one would expect, a lot has been learned since 1976 — both biologically and operationally. It is the intent of this paper to provide an operational overview of PCT based on the experiences of the company's program. However, it is acknowledged that there are differing opinions on many operational aspects of PCT. There are many large-scale PCT operations in Eastern Canada that function very efficiently, yet each differs in many respects. Although the contents of this paper largely reflect the experiences and opinions of Corner Brook Pulp and Paper, it is fair to say that many of the operational considerations discussed have broad acceptance in principle.

## PLANNING

In the context of selection of the treatment area, planning is very important, particularly from an industry viewpoint. Assuming that the underlying objective is to maximize the economic benefits of PCT, the following points should be considered:

1) *Prioritize higher-capability sites closest to the mill*: The tremendous effect of site capability on the economics of silvicultural treatments is often overlooked or underestimated. The costs of treating a poor site and a good site under similar densities and conditions are virtually the same, yet the return on the better sites can be many times greater. Similarly, it makes good sense to prioritize those sites closest to the mill. Economic gain is ultimately determined at the point of wood delivery to the mill yard.

2) *Maximum gain (fiber/$) is realized in lower density classes*: This is not to say that a given hectare with low tree density will respond to treatment better than a hectare with high density. As the cost per hectare for PCT is very sensitive to density, it is quite clear that more hectares with low density can be treated than of high density with a fixed number of dollars. Consequently, the resulting volumes or fiber per dollar will be much higher, treating *more* hectares with *lower* densities. All too often, foresters prioritize the higher-density stands "because they need it more!" As a related point, there is more gain in the final analysis thinning from 10,000 to 2,000 stems/ha than in thinning from 50,000 to 10,000 stems/ha.

3) *To achieve maximum gains in time, volume, or growth productivity, the "timing" of stand treatment is very important*: Piene (1981) demonstrated this very clearly with balsam fir in the Cape Breton Highlands. Piene concluded that delaying spacing beyond the point at which the crowns and root systems of crop trees are well developed in proportion to the stem results in significant volume losses. Contrary to common opinion on the effect of density on tree height, it was also concluded that the height growth of dominant and codominant trees was strongly affected by density. Therefore, from a planning viewpoint, it is very important to consider the "timing" of stand treatment. Taking the approach of prioritizing older, more stressed, backlog stands before their condition worsens will *not* produce maximum gains. For balsam fir, the ideal time for release treatment is generally at ages of 8 to 15 years, depending on density, when stands are approximately 2 to 3 m tall.

4) *Give preference to stands that will have the highest proportion of desirable species after treatment*: Through favoring the more desired species in the crop-tree selection process, the species composition of the post-treatment stand can change dramatically over what it would be if the stand was left to its own devices. It is not uncommon in Newfoundland to change the proportion of desired species (black spruce (*Picea mariana* [Mill.] B.S.P.) or white spruce (*Picea glauca* [Moench] Voss) over balsam fir) from < 5% before treatment to in excess of 50% after treatment.

## PCT SPECIFICATIONS

Well defined treatment specifications and standards are an important component of any PCT program. However, before these can be set down, it is necessary to first define the treatment objectives in such terms as end product (pulpwood, sawlogs or both), tree dimension at harvest, rotation age, and whether or not commercial thinnings or further stand entries are anticipated. Specifications for the spacing operation can then be defined, assuming, of course, that the manager has a basic knowledge or understanding of how these various specifications fit into a crop plan. Perhaps the most sensitive of specifications is that of residual density. If we define a stand as being mature when it reaches maximum mean annual increment, and decide not to harvest until it has reached this point, the selected residual density will have a major impact on the characteristics of the stand at rotation age. Although such factors as site capability, rotation age and merchantable volume/ha are all interrelated in this decision, it is tree diameter that is commonly of most interest to managers, and it is tree diameter at rotation age that is most affected by density. There is a strong relationship between stem diameter and crown diameter/width, which are both controlled by density or spacing.

Very often, there are small openings in the stand being treated and consequently workers may be instructed to leave crop trees "a little closer" around the edge of such openings. In setting specifications, it is necessary to define "how close is too close". Similarly, actual spacing distance can and should be varied somewhat to favor superior crop trees. Although it is clear that selection of crop trees should be left to the judgment of the cutters, they still require "specific" instructions on how to do this. For example, is it acceptable to leave two good crop trees 30 cm apart? Spacing flexibility must be defined. If you instruct cutters that spruce is preferred over balsam fir, the cutter will inevitably encounter situations in which he must choose between a poorly formed spruce 1 m tall and a vigorous, well formed balsam fir 3 m tall. Clearly, the manager should choose the balsam fir, but this is *not* the instruction the cutter has been given. Assuming that cutters know what you mean can be disastrous. If there are specific instructions for special situations, be sure to define them. If there is no softwood available at a specific spot, should the cutter leave a hardwood if it is available? If the hardwood is 5 m tall with a broad crown and the adjacent softwood crop trees are only 2 m tall, should the hardwood still be left? There are countless situations like these in any spacing program. If you want various situations to be handled in a certain way, you must be specific and not assume cutters will do it the way you would. If you want stumps cut below the lowest green branch, then say so. If you want the smaller trees less than 1 m tall (referred to as "whip trees" in Newfoundland) cut, then say so. Having a well defined set of specifications for PCT is very important to achieve maximum results.

## ORGANIZATION

The organization of a PCT program is all encompassing, comprising such matters as staffing, field layout/area control, incentive systems, quality control, administration and various other elements. As pointed out earlier, there are no two PCT programs by either industry, government or otherwise that are organized exactly the same way, yet most seem to function with some degree of efficiency. In terms of staffing, the organizational structure depends very much on the size of the operation and how it is distributed geographically. With Corner Brook Pulp and Paper, the basic work unit is a 12-man crew. A group of this size can be handled efficiently by one foreman, and by happy coincidence, fits very nicely in a 12-passenger bus. Each group of four to five crews has a supervisor and a quality checker to ensure consistency in all jobs. Corner Brook Pulp and Paper has three such groups, with a total of 13 12-man crews. To discuss the company's staff organization beyond this point would be impractical, as it would involve lengthy job descriptions and a discussion of the division of responsibilities. It will suffice to say that although there is obvious pressure from Management not to over-staff, understaffing represents poor economy and can produce disastrous results. The configuration of crew sizes, staffing and division of responsibilities is not as important as ensuring that *all* aspects of the job are tended to adequately.

Field layout and area control are also key elements of organization. With the Corner Brook operations, the treatment areas are laid out in the field with a hand compass and flagged in 60- to 80-m strips (mostly 60 m). These areas are then mapped on large sheets of metric graph paper with such details as density classes, openings, pieces to be omitted, etc. Workers are then assigned to particular strips and paid on the basis of rates that apply to seven different density classes. If a piecework system is to be employed, it is important to recognize that productivity depends on the densities encountered. At least in Newfoundland, there can be large differences in density, even within a particular strip. Establishing piecework rates based on density will be addressed later.

As it is imperative to keep down-time to an absolute minimum, it is necessary to provide spare brush saws on site in case of breakdowns. At Corner Brook Pulp and Paper, an effort is made to provide three spare saws for each crew of 12. Despite this, however, it is usually necessary to provide on-site mechanical facilities, particularly if the job is far from a regular service depot. Although a full-time mechanic may be employed where a number of crews are working in close proximity, it is common practice to use "cutter-mechanics" for crews working in isolation. A cutter-mechanic is a regular cutter on the 12-man crew who has a mechanical inclination and who repairs saws perhaps one day per week. Depending on his skill level, he usually performs the more minor repairs and leaves the larger jobs for the main service depot. This approach works very well for Corner Brook Pulp and Paper, as it improves overall efficiency.

## SAWS

For precommercial thinning in which the predominant tree size is from 2 to 8 cm in diameter, the safest and most efficient tool is the clearing saw or brush saw. This type of saw is far superior to chainsaws, which still have surprisingly wide usage in Canada. Productivity (area thinned) is conservatively estimated to be more than 50% greater than with chainsaws, and some argue that the productivity is doubled. The rotating blade cuts three times faster than a saw chain and makes it much easier to achieve directional felling. The brush saw operator works in a vertical position, whereas a chainsaw operator must stoop to cut each tree, exposing himself more to accidents and fatigue. The common arguments for the use of chainsaws in such diameter classes simply do not hold water in most cases. Some say "I can also use my chainsaw to cut pulpwood or firewood — it's more versatile!" A carpenter could make the same argument for not using a hammer because he can use the back end of his axe to drive nails as well as to do all the other things an axe was designed for. Others say "... but in the stands we are treating, we sometimes encounter trees 15 to 20 cm in diameter." Trees of this size can be handled easily with a clearing saw, though not as efficiently as with a chainsaw. However, if trees of this size are frequent, it becomes questionable whether the project is really precommercial thinning.

There are many models and sizes of clearing saws on the market. However, for industrial use in young stands with trees 2 to 8 cm in diameter, only the Husqvarna 165RX, Stihl 360 and Jonsered RS51 have thus far demonstrated a potential for use under Newfoundland stand conditions. Although the Husqvarna 165RX is undoubtedly the most popular saw in eastern Canada, Corner Brook Pulp and Paper operations have been dominated by Stihl products over the years. The company will be testing a new and larger prototype model (the Stihl 420) this summer. Currently, approximately one-third of the company's brush saws are Husqvarna 165 models; the remainder are Stihl 360 saws. Comparing different models of clearing saws is pointless, as each user seems to have a different experience and a different opinion. It may suffice to say that for industrial use under the stand conditions described above, either of the above models should prove satisfactory. Experience has shown that the minimum engine displacement required is in the 50-cc class.

## TRAINING

There is *nothing* more important in operational spacing than training. A well designed training program has a major impact on costs, quality and productivity. It is fair to say that most industrial programs have *some* sort of training for new workers. Corner Brook Pulp and Paper is no exception to this, with a home-made program that we were reasonably proud of until 1988. In early 1989, however, the company (in conjunction with Abitibi–Price and the Newfoundland Department of Forestry) acquired the services of NORDFOR Training and Consulting of Husqvarna, Sweden, to provide a "Train-the-Trainer" program for precommercial thinning with brush saws. Each agency selected a number of its best and most experienced workers to take part in the 2-week program. The results of this exercise were astounding, with all participants learning a great deal — both in the technical aspects of operating clearing saws and, more importantly, in how to teach other people. Although the training program should include such elements as crop-tree selection, quality assessment, first aid and clearing-saw maintenance, it is the work-planning and particularly the felling-technique (directional felling) components that have the greatest impact on worker productivity. The difference in productivity between an untrained and a trained worker is *at least* 50%. Of course, *safety* is paramount in any training program and is of particular importance in PCT. Although it is clear that clearing saws are a safer tool than chainsaws for PCT, the potential for accidents is still high for an untrained worker.

It is not difficult to convince people of the importance of training, *per se*. As noted earlier, there is nothing more important. However, the key point is that the training must be done by qualified people. With 14 years of experience in large-scale operational PCT, Corner Brook Pulp and Paper has come to realize that *training is a specialty*. If you have a medical problem, consult a doctor; if you have your wires crossed, consult an electrician; if you want a good training program, consult a training specialist.

## INCENTIVE SYSTEMS

One of the best ways to ensure mediocre productivity and high costs is to not have an incentive system. Even for salaried people, there is the lure of promotion or, at the very least, keeping one's job. Fortunately, PCT is one of the activities that lends itself nicely to a piecework system; i.e., the more one does, the more one is paid. In many unionized situations, however, there is also an associated guaranteed wage, with "bonus" earnings above this level. In either case, it becomes necessary to establish normal levels of productivity; i.e., the amount of work a person can be expected to do under a given set of conditions and in a given period of time. In the case of Corner Brook Pulp and Paper, a unionized operation with a guaranteed hourly wage, there is a minimum acceptable level of productivity required to justify payment of this guaranteed wage. Workers who cannot achieve this minimum productivity are dismissed as "unsuited" for PCT.

It can be appreciated that productivity (hectares treated/person-day) will vary depending on stand density or the degree of difficulty of working on the site. The minimum daily requirement (productivity) as a function of density for Corner Brook Pulp and Paper is shown in Figure 1. As can be seen, the relationship between density and productivity is not a straight line as one would expect, but rather it is a curved relationship — productivity *accelerates* with decreasing density. Although each agency in eastern Canada has constructed a somewhat different density/productivity relationship, virtually all are curved. In any case, it is generally on the basis of this minimum productivity curve that piecework rates are set.

Studies of incentive systems have examined "how big a carrot" is required for workers to go all out for maximum productivity. Although there are differing opinions

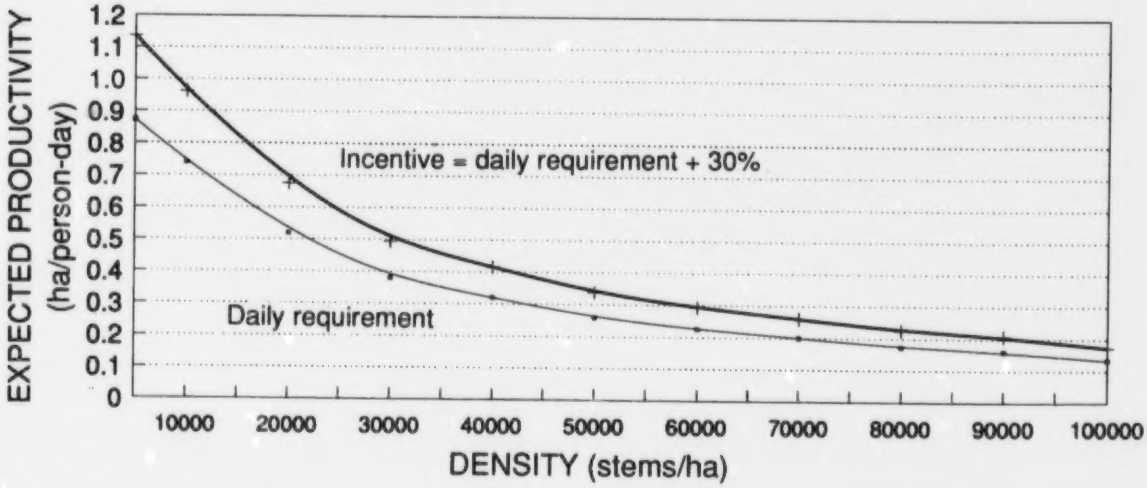

*Figure 1. The expected productivity, as a function of stand density, for workers conducting precommercial thinning.*

on this, a bonus of up to 30% above regular wages appears to be acceptable in most cases; i.e., the average worker should be able to earn 30% more dollars or exert 30% more effort than the minimum requirement expressed as a guaranteed wage. For Corner Brook Pulp and Paper's PCT operations, this level has proven to be quite effective. Therefore, the average actual level of productivity for each density class is approximately 30% greater than the minimum daily requirement, as shown in Figure 1. It should also be noted that although density is the primary factor in establishing the "degree of difficulty", it is not the only one. Factors such as slope, tree height, terrain, and surface obstacles (rocks, slash, stumps, etc.) all contribute to the degree of difficulty, and must be accounted for in a piecework system. In essence, any given worker should have the potential to make the same earnings regardless of stand conditions.

Although there are numerous ways to construct incentive systems, the key point is to have an incentive system designed to obtain maximum worker productivity at a lower overall cost.

## QUALITY CONTROL

The importance of quality is evident in virtually everything we do that is of any consequence. With PCT, quality control is particularly important. Simply put, the gains realized from PCT are proportional to the quality of the work done. Inadequate attention to quality control can produce disastrous results, so spending time and money in this direction is clearly economical.

A quality control program should ideally be structured around the established PCT specifications, whereby the quality of the actual work done is measured against a set standard for each specification. For Corner Brook Pulp and Paper, quality assessment is centered around the following elements:

- *Density*: The actual number of crop trees left after treatment.
- *Spacing*: The degree to which crop trees are distributed in relation to existing growing space.
- *Crop tree selection*: Selection of the best crop trees (form, dominance, preferred species, etc.).
- *Nicks*: Accidental damage to intended crop trees with the saw blade.
- *Green branches*: Stumps not cut below the lowest green branch.
- *Whip trees*: Trees substantially shorter than the general stand height that often get overlooked during the thinning operation. This class comprises trees shorter than 1 m or one-third of the adjacent crop tree's height.

A scoring system has been devised whereby each specification is measured or rated numerically. Also, because certain specifications have more importance than others, a "weighting factor" is assigned to each element or specification. The scoring system uses the rates and weights to provide a calculation of quality. Assessments are done on the basis of circular 0.01-ha plots. Penalties for below-standard quality take the form of payment deductions, which appear to be the most effective deterrent.

The main point to be made is that quality control is critically important to the success of a PCT operation. A formal assessment procedure with adequate deterrents is highly recommended.

## CONCLUSIONS

Although precommercial thinning has been practiced in Canada for quite some time, the level of activity has been relatively minor in comparison with reforestation efforts. It is now realized that planting trees does little or nothing to satisfy wood-supply deficits that will occur throughout many parts of Canada 25 to 35 years from now. In many cases, these impending shortages are the result of age-class imbalances. Since PCT can reduce the rotation ages of natural stands by 20 to 30 years, this treatment is gaining prominence because, among other things, it can bridge these age-class imbalances.

Many government agencies and companies are now contemplating large-scale or expanded PCT programs, and consequently require an appreciation and awareness of the operational considerations associated with this treatment. Though experience will undoubtedly be the best teacher, failure to adequately prepare for this operation will result in higher costs, higher accident frequency, lower quality and lower productivity... not to mention greater aggravation. In summary, attention should focus on the following:

- Planning: Select priority treatment areas for maximum gains.
- Treatment specifications: Define precisely how you want the job done.
- Organization: Plan staffing, field layout/area control, etc.
- Saws: Use clearing saws; avoid chainsaws.
- Training: Recognize that nothing is more important, and that training should be done by qualified people.
- Incentive system: Be aware that incentives are critically important for cost effectiveness.
- Quality control: Devise a comprehensive and formal procedure, with adequate penalties and rewards.

There are obviously many other operational factors to be dealt with in organizing a PCT operation, such as union considerations, administrative/clerical functions, transportation, etc., but the seven factors outlined above are particularly important and are basic to a successful operation.

## LITERATURE CITED

Piene, H. 1981. Early growth responses to operational spacing in young balsam fir stands on the Cape Breton Highlands, Nova Scotia. Dep. Environ., Can. For. Serv., Fredericton, N.B. Inf. Rep. M-X-125.

# BENEFITS OF SILVICULTURAL TRAINING

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## ABSTRACT

As the number and scope of silvicultural programs increase, so does the need for a skilled labor force. Training programs for occupations that have production-pay scales should utilize a production-oriented delivery model. This paper describes one such program and discusses the benefits to contractors who establish training programs for new workers.

## RÉSUMÉ

À mesure que le nombre de programmes silvicoles et que la portée de ces derniers augmentent, on assiste à un besoin grandissant de personnel qualifié. Les programmes de formation des emplois rétribués en fonction de la production devraient recourir à un modèle axé sur la production. L'auteur décrit un de ces programmes et examine les avantages que pourraient en retirer les chefs d'entreprise qui désirent mettre en œuvre des programmes de formation pour leurs nouveaux employés.

## INTRODUCTION

As use of the silvicultural treatment of spacing has increased in New Brunswick, so has the need for a highly skilled and productive labor force. In recent years, training has become directly linked to the development of this silvicultural labor force. The Miramichi College, in cooperation with industry, has developed a training model or approach that links production with training in order to address the labor requirements for skilled spacing-saw operators. This paper outlines some of the activities the Miramichi College has been involved in as well as the various benefits associated with training in silvicultural spacing.

## SILVICULTURAL TRAINING ACTIVITIES

The Miramichi College began vocational forestry training in 1984 with two regular programs, Professional Forest Worker and Silviculture Worker. These programs were combined in 1988 to form a single program called "Silviculture".

A Mobile Forest Training Unit was established in 1987 to provide responsive, "on-the-stump" training to New Brunswick's forest industry on a contract basis. This training unit has become a key component in the delivery of vocational silviculture training in New Brunswick.

The Mobile Forest Training Unit specializes in short, task-specific training programs that are tailored to the needs of the individual company. At present, the unit offers four vocational silviculture programs:

1. Spacing-saw Operation (SSO)
2. Spacing-saw Repair and Maintenance (SSRM)
3. Spacing-saw Foreman (SSF)
4. Tree-planting Foreman (TPF)

It took a period of time for the Mobile Forest Training Unit to become established. Table 1 outlines its activities since 1987.

Table 1. Silvicultural training activities of the Mobile Forest Training Unit of the New Brunswick Community College – Miramichi.

| Year | Number of participants, by program | | | |
|---|---|---|---|---|
| | SSO | SSRM | SSF | TPF |
| 1987 | 25 | 15 | 0 | 0 |
| 1988 | 49 | 30 | 0 | 0 |
| 1989 | 163 | 60 | 0 | 0 |
| 1990[a] | 82 | 160 | 12 | 12 |

[a] as of June 1990

## SPACING-SAW OPERATOR DEVELOPMENT

Traditionally, vocational training has failed to link the aspects of production or piecework with skills development. In 1988, the Miramichi College developed a training model that incorporated motivating factors that would assist in the development of a production-oriented silviculture worker.

The Spacing-saw Operator Program that the Miramichi College delivers has the following characteristics:

- Training must take place where the operator would normally work.
- Participants must be paid for work completed.
- Participants receive unemployment insurance, a training allowance or wages during the first 3 weeks as well as a piecework rate.
- Participants provide their own saw and other materials, and are provided with the going saw allowance.
- The training is task specific in that the prime objective is to teach spacing techniques only; spacing-saw repair and maintenance are covered after the first operating season.
- The company, contractor and worker have a vested interest in the training program.

The total duration of the training model is 160 hours and has three parts. Intensive training comprises 10 days, 2 to 3 days of classroom and shop work and 7 to 8 days of field work. Training support is delivered by a qualified trainer. Trainees are on salary and are provided with a saw allowance. Supervised job exposure comprises 5 days in the work environment, under close supervision by company/contractor supervisors. Trainees are on salary and are provided with a saw allowance. Finally, the on-the-job component comprises 5 days on a contract, with regular supervision and support. Trainees perform piecework and are provided with a saw allowance. Earnings/production from the previous 3 weeks goes towards this final week's earnings to assist in the transition phase.

The Spacing-saw Operator program covers the following topics: the spacing saw and related equipment, preventative maintenance, filing, spacing-saw safety, planning and job layout, spacing-saw operation and work techniques, species and quality selection, and pay-scale relations.

## BENEFITS OF TRAINING

The Miramichi College has not conducted a formal cost/benefit analysis of its silvicultural training; however, it has gathered data from the companies for which it has provided training over the last 4 years. Some of the benefits that have been identified are:

- Improved overall quality of the spacing.
- Increased earning potential for the worker.
- Reduced worker turnover (by 70%).
- Reduced supervision costs during spacing operations.
- Increased contractor profitability.
- Reduced the time required to develop a production worker.
- Reduced accidents.
- Instilled desire to learn in the worker.
- Improved completion of scheduled work.
- Stabilization of the labor force.

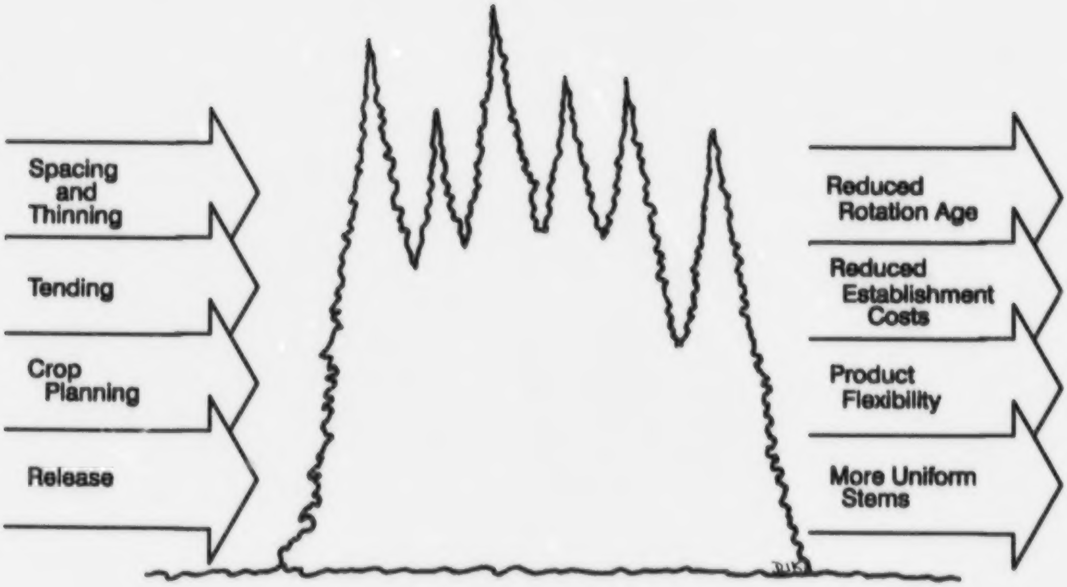
Over the last 4 years it has become apparent that there are substantial benefits in having a well trained silvicultural labor force.

## CONCLUSIONS

Silviculture workers should receive a formal production-oriented training program before commencing contracted spacing work. This training should be considered as an investment rather than an expense for the contractor.

Further research should be conducted in the areas of training methodologies and the cost/benefit relationships between silvicultural training and production work.

# SESSION V
## Management Consequences


Spacing and Thinning
Tending
Crop Planning
Release
Reduced Rotation Age
Reduced Establishment Costs
Product Flexibility
More Uniform Stems

# DEJA VU: "DOES IT PAY TO THIN YOUNG ASPEN?"

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## ABSTRACT

The research and development concerning thinning practices for aspen in the United States are reviewed. Throughout most of the country, thinning of aspen is not taken seriously; however, in the Lake States, thinning could shorten rotations for the production of aspen pulpwood and mitigate the imbalance of age classes that threatens to disrupt the flow of raw materials for the forest industry.

## RÉSUMÉ

L'auteur passe en revue les travaux de recherche et de développement poursuivis aux États-Unis sur l'éclaircie des peuplements de peupliers faux-trembles. Dans la majeure partie du pays, cette activité n'est pas vraiment prise au sérieux. Toutefois, dans les États des Grands Lacs, elle pourrait abréger la rotation pour la production de bois de pâte et atténuer le déséquilibre des classes d'âge qui menace de perturber l'envoi de matières premières par l'industrie forestière.

## INTRODUCTION

I chose the title of this paper for two reasons. First, I wanted to acknowledge the pioneering work in aspen (and other northern species as well) by Zigmond A. Zasada and his promotion of intensive management of aspen by asking "Does it pay...?" (Zasada 1952). Secondly, I wanted to explore why this question keeps coming around again and again, and why we do not embrace thinning in aspen as we do for other hardwoods and for many conifers. Why is thinning so often considered, yet so little practiced in the aspen cover type? To find the answers, I, like Ebenezer's Christmas ghosts, will take us first to the past to see how the question "Does it pay to thin young aspen?" came to be formulated, then to the present, where we still ask the question, and finally to the future, where the question will be answered.

## THE PAST

Virtually all the research on thinning aspen in the United States (see D. Weingartner, in this proceedings, for the Canadian experience) took place in the Lake States, and nearly all of that in Minnesota. The earliest documented thinning of aspen is in Utah, where Baker (1925) lightly thinned (10 to 21% of standing volume) some 40- to 70-year-old stands. After 5 years, gross production (including thinnings, increment, and mortality) was the same (+11%) as in unthinned stands. Net production (gross production less mortality), however, was +10% in thinned stands vs. +3% in unthinned stands. Baker, nonetheless, was not impressed because the gain was not considered to be worth the labor expended, and most of the increased radial growth occurred on smaller trees; dominant trees did not respond at all. Today, no long-term studies of thinning aspen exist in the American West (Mowrer 1988). Two studies were recently installed: one in 10- to 20-year-old aspen in western Colorado, begun in 1985, with 500, 1250 and 2500 trees/ha, and one in the Frazer Experimental Forest, in a 65-year-old stand thinned to 25, 50 and 75% of full basal area. Canker-infected wounds, sunscald, elk gnawing, snowbend and wind breakage have overcome the modest gains in growth of crop trees (W. Shepperd, USDA Forest Service, Ft. Collins, Colorado, personal communication). A thinned juvenile stand in the Mancos Ranger District of the San Juan National Forest (Colorado) apparently grew rapidly (Jones 1976), but this was not documented.

The answer from the West definitely appears to be that "No, thinning does not pay in terms of producing timber," but, as we shall see later, "it perhaps may pay" in terms of other forest values.

The only other American thinning study outside of Minnesota was in Michigan. Day (1958) thinned 10-, 20- and 28-year-old stands to 1880, 1330 to 1790 and 480 to 1090 trees/ha, respectively. Commercial thinnings from the oldest stand salvaged some volume that would have been lost to mortality, and in all cases radial growth and survival of crop trees improved. Day nevertheless avoided any outright recommendations, partly because the study results were confounded by damage by animals (plots were flooded by beavers), insects (especially the forest tent caterpillar, *Malacosoma disstria* Hbn.), and diseases (mostly *Hypoxylon mammatum* [Wahlenb.] J. Miller). In their book on aspen in the Lower Peninsula of Michigan, Graham et al. (1963) devoted all of one paragraph to thinning (p. 211). They extolled the virtues of precommercial thinning to promote both growth and stand health, but could offer little hope for economic efficiency. Was thinning worth the effort? "Hardly ever" was the answer from Michigan.

Minnesota is the mother lode for aspen thinning studies (Table 1). The objective of these studies was to develop techniques to improve the yield of sawtimber and match bolts. Thinnings were started in stands as young as 1 year and as old as 37 years. Studies were attempted as early as 1929 and as recently as 1977. Residual crop-tree densities ranged from 400 to 5000 trees/ha. Stands were thinned by hand and with logging equipment, precommercially and commercially, from above and from below, and from one to four times. All studies but one (a crop-tree crown release) were performed with classic spacing, in which only crop trees were left. Completed studies lasted from 15 to 40 years and yielded up to eight 5-year growth periods each. One study is ongoing (Perala and Laidly 1989). The results of the earliest studies were first summarized by Zehngraff (1949). Shortly after Zasada asked his question, a slick four-page, two-color bulletin (Anon. 1954) left little doubt that the answer was "Yes!". The silvicultural recommendations then were virtually the same as those espoused today, after nearly 40 years of fine-tuning. However, to my knowledge, not a hectare of aspen was operationally thinned until the late 1970s, after which comprehensive results were summarized by Hubbard (1972), Schlaegel (1972), and Brinkman and Roe (1975). Management recommendations based on these results are included in Perala (1977), Perala and Russell (1983), and Rauscher et al. (1990).

This rich database has led to several solid conclusions, the first from diverse lines of evidence: Stands should not be thinned before the crop trees attain an average DBH of 5 cm, at about 7 to 10 years of age. It takes nearly this long for dominance to be stabilized so that crop trees can be selected with confidence (Perala 1984). Meanwhile, dominance is so poorly expressed that new suckers arise for several years after thinning (Strothman and Heinselman 1957). Repeated cleaning of these suckers exhausts the supporting root system (Perala 1979) and paves the way for *Armillariella mellea* (Vahl. ex Fr.) Karst. root rot (Stanosz and Patton 1987). For these reasons, the 15-year results of a study of aspen thinned at age 1 (Sorensen 1968) should be ignored. Unfortunately, this study has been widely and erroneously cited as evidence that initial density makes little difference in aspen commercial yield.

Table 1. Thinning studies in Minnesota.

| Authors | Growth observations[a] | Site index (m, 50 yr) | Age (yr) | DBH (cm) |
|---|---|---|---|---|
| Hubbard (1972) | 6 | 27 | 7-24 | 3-14 |
|  | 4 | 27 | 31-49 | 16-28 |
| Noreen (1968) | 7 | 24 | 4-20 | 1-10 |
| Perala and Laidly (1989) | 48 | 25-31 | 5-21 | 1-13 |
| Schlaegel and Ringold (1971) | 4 | 26 | 37-47 | 17-23 |
| Sorensen (1968) | 30 | 21-23 | 1-15 | <1-11 |
| Zehngraff (1949), Perala (1978) | 48 | 23-25 | 13-53 | 4-31 |
| Zehngraff (1949), Zasada (1952), Schlaegel (1972), Brinkman and Roe (1975) | 89 | 18-26 | 10-62 | 5-35 |

[a] Growth observations = number of treatments X number of remeasurements; includes unthinned controls.

Other conclusions are more straightforward. As stands age, they respond less and less to thinning. At 37 years, the response is immeasurable (Schlaegel and Ringold 1971). Residual density after thinning should range from about 1400 trees/ha at age 10 to 500–600 trees/ha at age 30. Site index should be no less than 21 m at 50 years. Risk of *Hypoxylon* canker is important, but not easily predictable. Thinning should not be done from above, and the best trees should always be left for the final crop. Finally, thinning is intended primarily to produce sawtimber and veneer — pulpwood production alone is not profitable.

In Minnesota, the answer to our question had matured to a definite "maybe".

## THE PRESENT

Over the last decade and a half, at least 460 ha of juvenile aspen have been thinned operationally or in pilot tests in Minnesota and Wisconsin, most of it in strips by machines (Table 2). Another 60 to 80 ha are scheduled to be thinned annually by St. Louis County (B.S. Jones, St. Louis County Land Investment, Duluth, Minn., personal communication). No other plans have been announced, but sporadic operations by others are likely. The growth response of aspen to strip thinning is meagerly documented, but is being addressed by W.E. Berguson of the Natural Resources Research Institute, Duluth, Minnesota. Berguson is finding substantial increased height and radial growth of residual trees in the earliest operationally thinned stands mentioned above (Berguson, personal communication). Perala (1978) and Perala and Laidly (1989) also noted that height growth increased with thinning.

The renewed interest in thinning aspen in Minnesota is fueled by a projected shortfall in aspen supply by the year 2010 (Prosek 1988). An ambitious and timely thinning program could mitigate the aspen age-class imbalance by accelerating the growth of young stands into a merchantable condition (Berguson and Perala 1988, Jones et al. 1990). An enduring benefit will be the provision of an even flow of raw material in the future. It is ironic that increased demand for pulpwood has been the trigger for intensive management of aspen by means of a technology developed with increased production of sawtimber in mind.

Now the answer to our question is nearly "yes".

## THE FUTURE

Predicting the future is risky, but a reasonable forecast can be derived objectively. I will first list all the reasons to thin, and then all the reasons not to, while speculating on their validity and weight in the decision to thin. Zasada's (1952) reasons to thin included (1) increased yield and (2) higher wood quality, but also (3) an economic rate of return exceeding 3% in constant dollars. Perala (1983) and Berguson and Perala (1988) estimated returns of 6.2 to 9.5% under favorable circumstances. Zasada also cited (4) better regeneration conditions because fewer nonmerchantable trees would interfere with sucker growth, (5) rotations shortened by 10 to 15 years, (6) the ability to maintain utilization standards, and (7) the economics of handling larger material throughout the production stream. Jones and Shepperd (1985) added to this list opportunities to (8) upgrade genetic quality by removing substandard clones during thinnings, (9) improve aesthetics by increasing the line of sight into dense stands, and (10) improve the production of the ground layer for grazing and wildlife. Other positive features include (11) increased resistance to insect defoliation stress (Day 1958), (12) increased resistance to drought stress (Sucoff 1982), and (13) the already-mentioned opportunity to balance the age-class distribution to smooth the flow of raw materials and to enhance size- and age-class diversity for wildlife and aesthetics.

Table 2. Aspen operational thinnings and pilot tests in the Lake States.

| Location | Type of thinning | Area (ha) | Year completed | Stand age (year) | Cost ($U.S./ha) |
|---|---|---|---|---|---|
| Chippewa National Forest | Hand | 77 | 1978–1981 | 10–13 | (7.5–10)[a] |
| | Hand | 25 | 1983 | 9–13 | $273 |
| | Machine | 165 | 1976–1983 | 9–13 | $37–62 |
| | Machine | 24 | 1990 | 10 | $96 |
| Chequamegon National Forest | Hand | 10 | 1979 | 10 | (10) |
| St. Louis Co. (Minnesota) | Hand | 30 | 1989–1990 | 8–10 | $131 |
| | Machine | 26 | 1989–1990 | 8–10 | $32–72 |
| | Combined | 35 | 1989 | 8–12 | $168–212 |
| Blandin Forest Products (Minnesota) | Machine | 19 | 1989–1990 | 10 | $30–36 |
| Minn. Dep. Nat. Resour. Washburn Lake | Machine | 7 | 1990 | 10 | $141 |
| | Combined | 4 | 1990 | 10 | $185 |
| Cass Co. (Minnesota) | Machine | 5 | 1990 | 10 | $125 |
| Clearwater Co. (Minnesota) | Machine | 4 | 1990 | 10 | $36 |
| Koochiching Co. (Minnesota) | Machine | 2 | 1990 | 10 | $50 |

[a] Figures in parentheses represent person-days; all dollar values are unadjusted for inflation.

All these pluses are still legitimate, although fully mechanized harvest systems, tight utilization standards for a wider complement of species, and less need for large trees have diminished the importance of points (4), (6) and (7). Increased pressure from people may elevate the importance of (9), not only in terms of improving lines of sight but also to give a more varied view where aspen dominates. Thinning would also more quickly provide large trees, which are aesthetically appealing to many viewers. Heightened interest in ruffed grouse management may support point (10), to renew the critical brushy habitat that begins to give way as young pole stands age. Thinnings before age 20 might, in some cases, be counterproductive; however, leaving a 0.4-ha patch unthinned within each 4 ha of thinned area will provide sufficient security for the grouse (Gullion 1990). If global warming becomes a reality, points (11) and (12) may be especially important reasons to thin.

The strongest reason of all may well be (13). To make a dent in the age-class imbalance by thinning, however, will require a massive commitment that is difficult to make with the available decision tools. A new growth model now being evaluated is expected to improve growth predictions for both thinned and unthinned aspen (Perala and Gieszewski, manuscript under review). For the first time, the decision to thin will be made with a high degree of confidence in growth projections. The model will still need modification to handle growth for machine-thinned stands.

Reasons not to thin (Jones and Shepperd 1985) include lower wood quality from (1) poor form and (2) poor self pruning that leads to (3) wood discoloration and trunk rot, (4) increased infestation by the poplar borer (*Saperda calcarata* Say) and (5) increased *Hypoxylon* canker, and increased bark injuries (6) inflicted during thinning and from (7) sunscald, which promote stem cankers and rot. To this I would add (8) risk of wind or snow injury, (9) diminished aesthetic or recreational values, (10) limited investment funds, and (11) a continued supply of sawtimber from old-growth stands on good sites.

These negatives can be overcome, most with ease. Reasons (1)–(4), (7) and (8) are not problems in stands with recommended residual stand densities. *Hypoxylon* canker (5) can be managed by carefully selecting resistant stands or clones. Conscientious operations can control (6) and (9), although machine-thinned strips can be a tangle to walk through and can be aesthetically displeasing for a few years. Old-growth sawtimber (11) will become less and less available, and with the trend toward shorter rotations, the supply will dry up within a decade or so. This will then become a reason to thin.

The limitation of capital (10) is, in my opinion, the most problematical. With so many competing voices, it all depends on how society and industry rank the need to thin in the long list of wants. If the aspen supply crunch is perceived to be critical to maintaining the billions of dollars invested in new plants, thinning may indeed be the silviculture of choice. One must remember that species substitution and other technical fixes are options as well.

So, what will the answer be? I (gulp!) predict that no more than 5,000 ha of aspen will be thinned in the Lake States during the next two decades, and that any thinning commencing in the next century will be too late to help the aspen size-class imbalance expected. In the Rocky Mountains region, only a few trials and pilot tests will be installed. Some stands will be thinned for landscape or other special reasons. Indeed, wherever aspen is thinned, economic appraisals will include not only the timber outputs but also the advantages to wildlife and recreationists, and other benefits. For the foreseeable future, thinning of any species will not be justified on the basis of global climate change; it will be some time before this need is clear.

The answer to our question, "Does it pay to thin young aspen?", will be "Yes", but not for everyone.

## ACKNOWLEDGMENTS

I thank W. Berguson, R. Brittain, B. Jones and R. Paddock for providing the data for Table 2. They and J. Bondioli, L. Burde, G. Gullion, M. Lucas, T. Mowrer and W. Shepperd significantly improved this paper by critically reviewing earlier versions. My apologies to Charles Dickens.

## LITERATURE CITED

Anon. 1954. Thinning aspen woods will pay! For. Industries Inf. Comm., Duluth, Minn. For. Bull. 4.

Baker, F.S. 1925. Aspen in the central Rocky Mountain region. USDA, Washington, D.C. Bull. 1291.

Berguson, W.E. and Perala, D.A. 1988. Aspen fertilization and thinning research results and future potential. p. 176–183 *in* A.R. Ek and H.M. Hoganson, *Ed*. Proc. Minnesota's timber supply: perspectives and analysis. Coll. Nat. Resour. and Agric. Exp. Stn., Dep. For. Resour., Univ. Minnesota, St. Paul. Staff Paper Series, Rep. 64.

Brinkman, K.A. and Roe, E.I. 1975. Quaking aspen: silvics and management in the Lake States. USDA For. Serv., Washington, D.C. Agric. Handbk. 486.

Day, M.W. 1958. Thinning aspen in Upper Michigan. Quart. Bull. Michigan Agric. Exp. Stn. 41:311-320.

Graham, S.A., Harrison, R.P. Jr. and Westell, C.E. Jr. 1963. Aspens: phoenix trees of the Great Lakes region. Univ. Michigan Press, Ann Arbor.

Gullion, G.W. 1990. Management of aspen for ruffed grouse and other wildlife — an update. p. 133–143 *in* R.D. Adams, *Ed.* Proc. Aspen Symp. '89, 25–27 July, Duluth, Minn. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Gen. Tech. Rep. NC-140.

Hubbard, J.W. 1972. Effects of thinning on growth and yield. p. 126–130 *in* Aspen Symp. Proc. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Gen. Tech. Rep. NC-1.

Jones, J.R. 1976. Aspen harvesting and reproduction. p. 30–34 *in* Proc. Symp. Utilization and marketing as tools for aspen management in the Rocky Mountains. 8–9 September, Fort Collins, Colorado. USDA For. Serv., Rocky Mountain For. Exp. Stn., Ft. Collins, Colorado, Gen. Tech. Rep. RM-29.

Jones, B.S., Berguson, W.E. and Vogel, J.J. 1990. Aspen thinning as a viable cultural tool. p. 205–210 *in* R.D. Adams, *Ed.* Proc. Aspen Symp. '89, 25–27 July, Duluth, Minn. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Gen. Tech. Rep. NC-140.

Jones, J.R. and Shepperd, W.D. 1985. Intermediate treatments. p. 209–216 *in* N.V. Debyle and R.P. Winokur, *Ed.* Aspen: ecology and management in the western United States. USDA For. Serv., Rocky Mountain For. Exp. Stn., Ft. Collins, Colorado, Gen. Tech. Rep. RM-119.

Mowrer, H.T. 1988. Is managing aspen density worthwhile? p. 201–209 *in* W.C. Schmidt, *Comp.* Proceedings — future forests of the Mountain West: a stand culture symposium. 29 September–3 October 1986, Missoula, Mont. USDA For. Serv., Intermountain Res. Stn., Ogden, Utah, Gen. Tech. Rep. INT-243.

Noreen, P.A. 1968. Economic evaluation of precommercial thinning in good-site aspen. M.S. major report, Univ. Minnesota, St. Paul.

Perala, D.A. 1977. Manager's handbook for aspen in the North-Central States. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Gen. Tech. Rep. NC-36.

Perala, D.A. 1978. Thinning strategies for aspen: a prediction model. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Res. Pap. NC-161.

Perala, D.A. 1979. Regeneration and productivity of aspen grown on repeated short rotations. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Res. Pap. NC-176.

Perala, D.A. 1983. Growth response and economics of thinning and fertilizing aspen and paper birch. p. 100–110 *in* J.C. Stier, *Ed.* Proc. Silviculture of established stands in north-central forests; the First Society of American Foresters Region V Technical Conference, Duluth, Minn., 14–16 September 1983. Soc. Amer. For., Washington, D.C. Publ. 83-11.

Perala, D.A. 1984. How endemic injuries affect early growth of aspen suckers. Can. J. For. Res. 14:755-762.

Perala, D.A. and Laidly, P.R. 1989. Growth of thinned and fertilized quaking aspen. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Res. Pap. NC-286.

Perala, D.A. and Russell, J. 1983. Aspen. p. 113–115 *in* R.M. Burns, *Tech. comp.* Silvicultural systems for the major forest types of the United States (revised). USDA For. Serv., Washington, D.C. Agric. Handbk. 445.

Prosek, C. 1988. Aspen supply — a DNR perspective. p. 188–194 *in* A.R. Ek and H.M. Hoganson, *Ed.* Proc. Minnesota's timber supply: perspectives and analysis. Coll. Nat. Resour. and Agric. Exp. Stn., Dep. For. Resour., Univ. Minnesota, St. Paul. Staff Paper Series, Rep. 64.

Rauscher, H.M., Perala, D.A. and Host, G.E. 1990. An aspen forest management advisory system. p. 185–194 *in* R.D. Adams, *Ed.* Proc. Aspen Symp. '89, 25–27 July, Duluth, Minn. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Gen. Tech. Rep. NC-140.

Schlaegel, B.E. 1972. Growth and yield of managed stands. p. 109–112 *in* Aspen Symp. Proc. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Gen. Tech. Rep. NC-1.

Schlaegel, B.E. and Ringold, S.B. 1971. Thinning pole-sized aspen has no effect on number of veneer trees or total yield. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Res. Note NC-121.

Sorensen, R.W. 1968. Size of aspen crop trees little affected by initial sucker density. USDA For. Serv., North Central For. Exp. Stn., Grand Rapids, Minn. Res. Note NC-51.

Stanosz, G.R. and Patton, R.F. 1987. *Armillaria* root rot in aspen stands after repeated short rotations. Can. J. For. Res. 17:1001-1005.

Strothman, R.O. and Heinselman, M.L. 1957. Five-year results in an aspen sucker density study. USDA For.

Serv., Lake States For. Exp. Stn., St. Paul, Minn. Tech. Note LS-490.

Sucoff, E. 1982. Water relations of the aspens. Univ. Minn., Agric. Exp. Stn., Tech. Bull. 338.

Zasada, Z.A. 1952. Does it pay to thin young aspen? J. For. 50:747-748.

Zehngraff, P.J. 1949. Aspen as a forest crop. J. For. 47:555-565.

# SPACING AND THINNING IN ASPEN AND MIXEDWOOD: SOME THOUGHTS, THEORIES AND OBSERVATIONS

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## ABSTRACT

Precommercial thinning or spacing of aspen (*Populus tremuloides* Michx.) may be required to maintain or enhance stand vigor early in the rotation. In boreal mixedwoods, this early release can provide an increase in the coniferous component or accelerate the growth of planted conifers, and can also maintain the value of the stand for wildlife habitat.

## RÉSUMÉ

Il est peut-être nécessaire de procéder à une éclaircie précommerciale ou à l'espacement des peupliers faux-trembles (*Populus tremuloides* Michx.) afin d'améliorer ou de maintenir la vigueur d'un peuplement au début d'une révolution. Dans les forêts mixtes de la zone boréale, cette coupe de dégagement hâtive peut se traduire par un accroissement du nombre de conifères ou accélérer la croissance des conifères plantés et peut également maintenir la valeur que revêt le peuplement pour la faune.

## INTRODUCTION

In closed, undisturbed aspen (*Populus tremuloides* Michx.) stands, all of the trees are under varying types and levels of stress. The main physiological stresses may be caused by deficiencies in light, moisture, or nutrients as a result of competition. Trees freed of competition by opening the canopy should develop at a faster rate if their physiologies can take advantage of the increase in available resources.

How do we know when an aspen stand needs to be thinned, when the coniferous regeneration in a mixedwood stand needs to be released, or if the treated trees will respond in the desired manner? Perhaps we don't, and that is why the definition of silviculture indicates that it is the art as well as the science of producing forest crops. At the biological level, our understanding of the factors responsible for growth and species interactions (including those with fungi and wildlife) is marginal, and our mensurational volume estimates may not be accurate.

## ASPEN THINNING STUDY

### Stand Conditions and Treatments

Three aspen stands in the 5-year age class (age 4 to 6 years) were systematically thinned to square spacings of 2, 3, 4 and 5 m to simulate mechanical thinning followed by manual thinning to the final spacing. If precommercial thinning is to become an economically viable silvicultural option in Ontario, mechanization of most of the process will be necessary because of the scale of the task.

The stands are located in the boreal forest region of northern Ontario in Dryden District (49°30′N, 93°0′W ), Terrace Bay District (49°30′N, 85°30′W) and Timmins District (48°15′N, 81°15′W). The soil types in the three areas are clay (Dryden), sandy loam to loam (Terrace Bay), and loam (Timmins).

Densities of aspen suckers at the time of treatment were 44,500, 26,100, and 11,250 stems/ha for the Timmins, Dryden and Terrace Bay stands, respectively. The low sucker density in the Terrace Bay stand was the result of scarification at the end of the first growing season in preparation for the planting of white spruce (*Picea glauca* [Moench] Voss) seedlings. Thinning to the fixed spacings removed 78 to 99% of the aspen stems. All other woody vegetation was cut to a 15-cm stump or less, except for coniferous regeneration in the Dryden and Terrace Bay stands.

Sample trees were evaluated for height, diameter at breast height (DBH) and diameter at three-tenths of total height. Assessments were made at the time of treatment, annually during the first 5-year period, and at the end of the second 5-year period. Height growth of the planted white spruce in the Terrace Bay stand was evaluated in the fifth growing season after treatment.

Sample aspen tree volumes were estimated by means of the method described by Forslund (1982). This method reduces the error associated with visually imperceptible differences in bole shape. Grossly inaccurate volume estimates may result when bole shape is not considered (see the appendix on volume estimation).

## THOUGHTS, THEORIES AND OBSERVATIONS

When evaluating the effects of a silvicultural treatment on mensurational parameters, the results are usually presented as statistical summaries and the presence or absence of significant treatment effects. In the following section, the figure lacks a scale on the Y axis to draw the reader's attention to the effect of the treatment on the trajectory of a parameter's growth curve. Small changes in the trajectory of the growth curves made early in the rotation may have a profound influence on the mensurational parameters' and possibly indicate changes in the wood properties of the trees that will be harvested.

### Diameter growth

Most reports of aspen thinning experiments have indicated a favorable diameter response to a reduction in stand density (Bickerstaff 1946, Steneker 1964, Bella 1975). A diameter response was evident in the three study stands the first growing season after treatment. The initial response, as indicated by the difference in the slopes of the diameter trend lines for the thinned and control plots, was small the first season after treatment in the Timmins (Fig. 1) and Terrace Bay stands. The Dryden stand appeared to respond more vigorously to thinning than the other two stands based on the difference in the slopes of the trend lines for the control and thinned plots. In all three stands, the diameter accumulation in the thinned plots was substantially greater in the thinned than in the unthinned plots by the 10th year after treatment.

### Height growth

Aspen thinning studies that used height growth as a parameter for evaluating the response to different treatments have generally indicated that height growth is unresponsive to thinning (Bickerstaff 1946, Steneker 1964, Bella 1975). For the Dryden stand, thinning to square spacings between 2 and 5 m increased height growth over that of the unthinned control during the 10-year period since treatment. This increase in height growth could be the result of increased moisture availability after thinning. Site index is strongly related to available soil moisture (Stoeckeler 1948, Strothmann 1960, Fralish and Loucks 1975); therefore, height growth is linked to the availability of soil moisture.

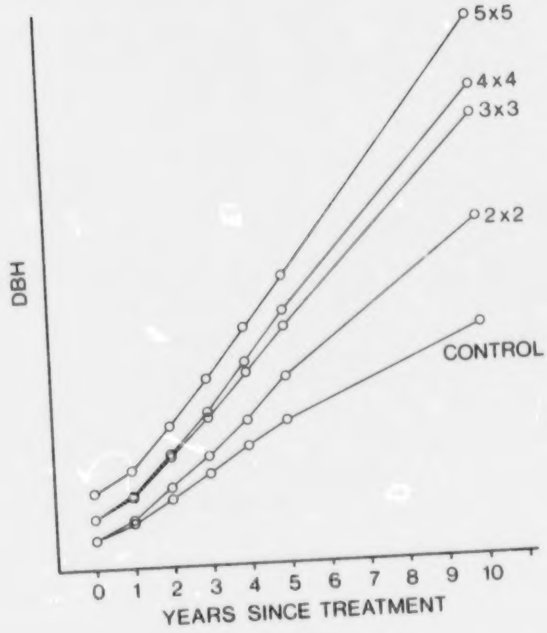

*Figure 1. Diameter trend, by treatment, after thinning in Timmins District. This graph is representative, in a qualitative sense, of the trends for stands in other Districts discussed below.*

An apparent decrease in height growth of the thinned plots during the first 5-year period at Timmins could represent a thigmomorphogenic response after a reduction of the intense competition on the site. "Thigmomorphogenic" refers to a reduction in cell elongation resulting from increased ethylene production caused by the increased stem flexing that occurs in thinned plots; in closed stands, crowns of adjacent trees buffer each other against wind and minimize flexing. This topic is described in more detail by Biro and Jaffe (1984) and Telewski and Jaffe (1986).

The Terrace Bay stand showed no height response to the thinning treatments. The lack of response was probably a result of incomplete utilization of the site by the stand of suckers that remained after scarification in spite of the moderately high stand density.

### Stand volume

Ten years after treatment, the control plots contained estimated average total stand volumes of 221, 77 and 79 $m^3$/ha for the Timmins, Dryden, and Terrace Bay stands, respectively. In contrast, the average volumes on the thinned plots were only 6 to 50% of those on the control plots, with one exception: at Dryden, the plots thinned to the 2- x 2-m spacing had an average volume that was 90% of the average control plot volume. The approaching equality of plot volumes between the control and 2-m spacing treatments is the net result of increased growth in the thinned plots and a high rate of mortality in the control plots. The average volume in the 2-m treatment will probably exceed that in the control within the next year or two; continuing high mortality is anticipated in the control plots as a result of competitive stresses and forest tent caterpillar (*Malacosoma disstria* Hbn.) defoliation.

The extremely high volume in the control plots in the Timmins stand is the result of the maintenance of high stem densities. If the reduction in the slope of the height trend curve in the control plots during the second 5-year growth period is any indication of the competitive stress in these plots, a major episode of increased mortality may be imminent. Prediction of mortality (by self-thinning) in second-growth aspen stands is probably the greatest obstacle to modeling stand growth, because individuals succumb apparently at random, for unknown reasons.

The similarity in the volumes of the Terrace Bay and Dryden control plots is interesting, since the sucker density is still about 90% of what it was 10 years ago at Terrace Bay and about 25% of the initial density at Dryden. As suggested above, the Terrace Bay stand had not undergone much competitive stress. Perhaps self-thinning will begin to occur in these control plots during the next 5-year period.

### Mixedwood and conifer establishment

Natural regeneration of balsam fir (*Abies balsamea* [L.] Mill.) and white spruce seedlings after thinning to 4- x 4-m and 5- x 5-m spacings was observed in one replication at the Timmins study area. In the 5-m spacing, coniferous regeneration totalled about 2,500 stems/ha. Regrowth of competing vegetation was relatively sparse in this replication and was composed mostly of ericaceous shrubs. The other replications showed no significant amounts of coniferous regeneration because of vigorous competition or lack of an appropriate seed source. Vegetation that typically regenerates vegatively as large patches (i.e., grasses, hazel [*Corylus cornuta* Marsh.] and alder [*Alnus* spp.]) appeared to restrict the establishment of coniferous seedlings more than did mixtures of individual plants of different species.

In the Dryden stand, coniferous regeneration was scattered throughout most of the thinned plots that have or had an available seed source. Competition from brush and new aspen suckers was kept under control by browsing moose (*Alces alces*). The spruce regeneration was developing satisfactorily, but much of the fir was being browsed quite heavily.

An assessment of the planted white spruce at Terrace Bay, carried out in the fifth growing season after thinning, indicated that there was no difference in height growth between the thinned and unthinned plots. Perhaps the response, if one occurred, was in diameter growth. If the release response of spruce is similar to that of aspen, with diameter the most responsive parameter, a minimum diameter or stem volume should be part of the free-to-grow criteria used to evaluate the establishment of plantations.

### Disease and decay

*Hypoxylon mammatum* (Wahlenb.) J. Miller, a fungus that causes a canker disease of aspen, was present to some degree in all treatments, but was more evident at the wider spacings (4 and 5 m). According to a recent review (Manion and Griffin 1986) on *Hypoxylon* canker, it appears that our understanding of this complex disease is insufficient to make practical management recommendations to reduce its occurrence in managed aspen. Interestingly, Manion and Griffin pointed out that the incidence of *Hypoxylon* may be related to increased moisture stress, which results in increased proline production, which in turn stimulates the growth of *Hypoxylon*. Anderson and Martin (1981) found lower stand density and defoliation by the forest tent caterpillar to be related to increased incidence of *Hypoxylon* canker. Manion and Griffin (1986) indicated that *Hypoxylon* canker is just one of a number of disease problems faced when managing aspen.

The most common problem encountered in aspen is the significant volumes of stain and decay in mature stems resulting from oxidation or caused by any number of organisms. Examinations of relationships between site and tree factors and the levels of defect encountered have not been very productive avenues of investigation over the years. The difficulty is in the manner in which the variables have been examined and the interpretation of the results.

One factor that affects the amount of defect within an individual aspen tree, clone, or stand may be vigor. The idea that the fastest growing aspen clones would also be the least defective is intuitively appealing. However, Basham (1987) found a majority of the fastest growing clones to be the most defective.

In unmanaged aspen stands, the trees are affected by competitive stresses and are not growing freely when the limits of one or more of the site's resources are approached. Under these conditions, higher levels of defect were related to crown class in many cases (Weingartner and Basham 1985); trees with the lower crown classes were the most defective.

Will the defect levels in thinned, vigorously growing aspen stands be lower than those encountered in unthinned aspen stands? This topic has not been addressed in the literature, and it takes approximately 15 years to allow differences in sample plots to develop. A tentative indication based on observations of unthinned stands is that thinned aspen stands would have less defect than unthinned stands. In unthinned stands, the development of defect appears to be quite rapid when growth is significantly restricted for an extended period by moisture or other factors.

### Wildlife habitat and use

Does thinning improve wildlife habit by increasing the diversity of vegetation and maintaining the early successional nature of the stand? The Dryden stand had at least one nesting grouse (*Bonasa umbellus*), and was frequented by deer (*Odocoileus virginianus*) and moose before treatment. Ten years after thinning, the moose have maintained the aspen regrowth and other desirable browse in a well-trimmed condition. They have also broken the tops out of some of the weaker suppressed trees that were released, and have killed an occasional vigorous tree by using it as a rubbing post to remove antler velvet. The Timmins and Terrace Bay stands had no indications of being used regularly by ungulates at the time of thinning. During the first 5-year period after thinning, there was no indication that the two stands were used regularly by ungulates, and 10 years after treatment, the amount of ungulate signs in the plots suggests this trend is continuing.

What is the difference between the areas? Is the stand at Dryden in close proximity to other habitat that is desirable for moose? The answer is probably yes. Another aspen stand in the 10-year age class was frequented by moose at the time of thinning and showed significant indication that it was still being used by moose 9 years after treatment. The stands are similar in that they lie between suitable terrestrial and aquatic habitats. On the other hand, the Timmins and Terrace Bay stands do not appear to be in the proper proximity to other suitable moose habitat.

## SUMMARY AND CONCLUSIONS

The diameter growth of released aspen stems is accelerated and this will shorten the time required to produce merchantable material. Height growth may be accelerated on sites or in regions where moisture or other stresses limit the full phenotypic expression of height-growth potential. Initiating aspen thinning as an operational treatment must be recognized as a long-term investment that may or may not produce increased yields of harvestable material. In mixedwood stands, thinning aspen could possibly assist in maintaining the vigor of the coniferous component. An increase in the coniferous component of mixedwood stands may result after aspen thinning, provided that a seed source is available and that microsites suitable for establishment exist within the regrowth. The synecology of diseases and decay fungi with aspen, as influenced by thinning, requires more study. Thinning can maintain or produce suitable habitat for ungulates and other species that require the diverse vegetation of an early successional sere. Thinning aspen as a primary crop in pure stands, or as a secondary crop with conifers in mixedwood stands, may be a viable management option when considered in an ecological context.

## LITERATURE CITED

Anderson, G.W. and Martin, M.P. 1981. Factors related to incidence of *Hypoxylon* cankers in aspen and survival of cankered trees. For. Sci. 27(3):461–476.

Basham, J. 1987. Assessment and prediction of stem decay in aspen stands. p. 110–117 *in* Aspen Quality Workshop. 12 Feb. 1987. Gov't of Can., Can. For. Serv. and Alta. For. Serv., Edmonton, Alta. FRDA Rep.

Bella, I.E. 1975. Growth-density relations in young aspen sucker stands. Dep. Environ., Can. For. Serv., Edmonton, Alta. Inf. Rep. NOR-X-124. 12 p.

Bickerstaff, A. 1946. The effect of thinning upon the growth and yield of aspen stands. Can. Dep. Mines and Resour., Ottawa, Ont. Silvic. Res. Note No. 80. 25 p. + appendix.

Biro, R.L. and Jaffe, M.J. 1984. Thigmomorphogenesis: ethylene evolution and its role in the changes observed in mechanically perturbed bean plants. Physiol. Plant. 62:289–296.

Forslund, R.R. 1982. A geometrical model based on the location of the centre of gravity of the bole. Can. J. For. Res. 12:215–221.

Fralish, J.S. and Loucks, O.L. 1975. Site quality evaluation models for aspen (*Populus tremuloides* Michx.) in Wisconsin. Can. J. For. Res. 5:523–528.

Manion, P.D. and Griffin, D.H. 1986. Sixty-five years of research on *Hypoxylon* canker of aspen. Plant Dis. 70(8):803–808.

Steneker, G.A. 1964. Ten-year results of thinning 14-, 19- and 23-year-old aspen to different spacings. Can. Dep. For., Ottawa, Ont. Publ. No. 1038. 22 p.

Stoeckeler, J.H. 1948. The growth of quaking aspen as affected by soil properties and fire. J. For. 46:727–737.

Strothmann, R.O. 1960. Evaluating the growth potential of aspen lands in northern Minnesota. USDA For. Serv., Lake States For. Exp. Stn., St. Paul, Minn. Pap. No. 86. 20 p.

Telewski, F.W. and Jaffe, M.J. 1986. Thigmomorphogenesis: the role of ethylene in the response of *Pinus taeda* and *Abies fraseri* to mechanical perturbation. Physiol. Plant. 66:227–233.

Weingartner, D.H. and Basham, J.T. 1985. Variations in the growth and defect of aspen (*Populus tremuloides* Michx.) clones in northern Ontario. Ont. Min. Nat. Resour., Maple, Ont. For. Res. Rep. No. 111. 26 p.

## APPENDIX: VOLUME ESTIMATION

One of the most critical operations that we engage in as foresters, technicians or researchers is the measurement of trees for the determination of stand volume. Typically, a model with total height (HT) and diameter at breast height (DBH) as parameters is used to estimate stem volume. For the most part, our volume estimates are reasonable. However, what happens when a silvicultural treatment, a genotype, or site factors affect the shape of the trees?

Consider the volumes of two geometric solids representing idealized trees with equal HT and DBH (Fig. 2). A paraboloid has 40% more volume than a cone when both have HT = 20 m and DBH = 20 cm. Using a volume model of a geometric solid (paracone) with a center of gravity at three-tenths of total height (the same center of gravity as aspen boles [Forslund 1982]), and using HT and DBH as measurement parameters, the volume of the cone is overestimated by 18.6%. If silvicultural or other factors result in an increase in the diameter of the lower stem, causing the bole shape to approach that of a cone, gross volume overestimates result if HT and DBH are used in the model. Using the diameter at three-tenths of total height (D.3) and HT in the geometric model, the volume of the cone is overestimated by 1.25% and the volume of the paraboloid is underestimated by 3.7%. Both of these estimates are well within the range of what might be considered acceptable error.

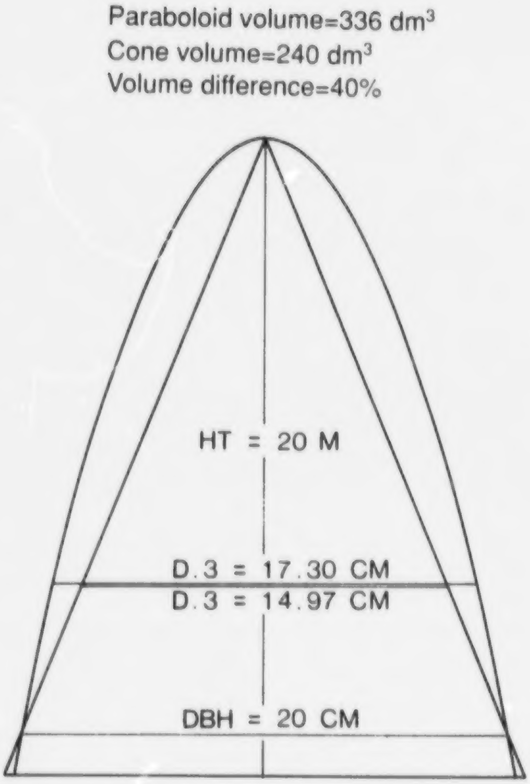

*Figure 2. Volume comparison for a cone and a paraboloid with equal height (HT) and diameter at breast height (DBH), but different diameters at three-tenths of total height (D.3).*

# COMMERCIAL THINNING IN MID-AGED, NATURALLY REGENERATED JACK PINE STANDS — IS IT WORTHWHILE?

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## ABSTRACT

The feasibility and benefit of thinning mid-aged (35- to 50-year-old), naturally regenerated jack pine (*Pinus banksiana* Lamb.) stands, with no previous stand tending, are examined.

Two commercially strip-thinned jack pine stands (site class 2) in Nimitz and Dupuis townships, approximately 25 km south-southeast of Chapleau, Ontario, were studied during the summers of 1988 and 1989. Based on the data collected, numerous questions arose in regard to the benefit of strip thinning. In the Nimitz Township study site, there appeared to be a positive response to thinning, whereas in the Dupuis Township area there appeared to be no significant effect.

In both cases it was felt that selective thinning would have yielded better results in terms of stand quality. Selective thinning was simulated with data from two untended, naturally regenerated jack pine stands near Thunder Bay, Ontario (site class 1, Raith, and site class 3, Sackville Township). It was estimated that from 50 to 100 $m^3$ solid outside bark (sob)/ha could be removed, depending on utilization standard and site class. The average stem sizes for material removed (outside bark DBH ≥ 10 cm) were 0.07 and 0.11 $m^3$ (sob) for the Sackville and Raith sites, respectively.

With today's lumber market and prices there is little incentive to thin mid-aged jack pine stands for the purpose of growing commodity-grade logs. Some data is presented on the residual value of wood sawn into SPF (spruce-pine-fir) 2 x 4 studs or used for Northern Bleached Softwood Kraft Pulp.

## RÉSUMÉ

La faisabilité et les avantages d'éclaircir les peuplements de pins gris (*Pinus banksiana* Lamb.) régénérés naturellement d'âge moyen (de 35 à 50 ans) n'ayant reçu auparavant aucun soin sylvicole sont examinés.

Deux peuplements de pins gris (stations de classe 2), situés dans les cantons de Nimitz et de Dupuis, à environ 25 km au sud-sud-est de Chapleau (Ontario), qui avaient subi une éclaircie commerciale en bandes, ont été étudiés au cours des étés 1988 et 1989. Les données recueillies ont soulevé de nombreuses questions concernant les avantages de l'éclaircie en bandes. Alors qu'à la station du canton de Nimitz, l'éclaircie a semblé avoir eu un effet positif, elle n'a semblé avoir eu aucun effet notable à celle du canton Dupuis.

Dans les deux cas, il a été jugé qu'une éclaircie sélective aurait donné de meilleurs résultats pour la qualité du peuplement. Une telle éclaircie a été simulée à l'aide de données provenant de deux peuplements de pins gris, régénérés naturellement, n'ayant subi aucun traitement, situés près de Thunder Bay (Ontario) dans les cantons de Raith (station de classe 1) et de Sackville (station de classe 3). Il a été estimé que de 50 à 100 $m^3$/ha pourraient y être récoltés, selon la norme d'utilisation et la classe de station. Les volumes moyens des tiges récoltées (dhp sur écorce ≥ 10 cm) étaient de 0,07 et de 0,11 $m^3$ pour les stations de Sackville et de Raith respectivement.

Compte tenu des conditions actuelles du marché et des prix du bois, il y a peu d'intérêt à éclaircir des peuplements de pins gris d'âge moyen en vue de produire du bois ordinaire. Des données sont présentées sur la possibilité d'utiliser le bois pour produire des bois de charpente (2 sur 4) ou de la pâte kraft blanchie de résineux de l'hémisphère Nord.

## INTRODUCTION

There is a lack of data regarding the costs and benefits of commercial thinning in naturally regenerated, mid-aged (35- to 50-year-old) jack pine (*Pinus banksiana* Lamb.) stands. Although other commercially thinned stands may exist, only two of significant size were found in Ontario; both were studies conducted by the Great Lakes Forestry Centre, Forestry Canada. The stands are located in Nimitz and Dupuis townships, approximately 25 km south-southeast of Chapleau, Ontario, were originally classed as site class 2 (Plonski 1981), and were strip-thinned (in 1970, at age 45) by means of conventional shortwood logging and a Timberjack RW-30 tree-length harvester (in 1973 at age 48), respectively. Complete descriptions of the sites and studies can be found in Mattice and Riley (1975), Mattice and Curtis (1978), Smith and Oerlemans (1988) and McLaughlin (1989). Smith and Oerlemans also presented a financial evaluation for the Nimitz thinning study.

Selective commercial thinning in mid-aged jack pine stands, as in most coniferous stands, could result in the following benefits:

- some return on investment from a stand earlier in its life (i.e., before rotation age);
- salvaging trees that would otherwise die as a result of competition, thus increasing the total volume utilized per hectare;
- removing poorly formed trees and undesirable species, and concentrating growth on the remaining crop trees;
- faster growth of crop trees;
- shortening the rotation;
- some "pruning" of dead branches as trees are felled during thinning operations (especially during winter, when branches are frozen and brittle); and
- lower final harvesting costs as a result of larger, better-formed trees and fewer unmerchantable trees.

On the other hand, strip thinning has been shown to result in some positive cash flow earlier in the stand's life and increased growth of trees close to the edges of the cut strips (Smith and Oerlemans 1988). In the study, there was also some growth response in trees within the leave strips. However, strip thinning does not take into account variations in stand density within a stand and the quality of the stand is not necessarily improved. Jameson (1956) compared strip and spaced thinning in 30-, 40- and 60-year-old jack pine. Spaced thinning produced the best response, but strip thinning also produced a positive growth response. In both cases, however, care had to be taken during the thinning operation to minimize damage to the remaining crop trees: i.e., wounds to the stem and roots are entrance points for decay fungi. Wounds to the stem also result in a lower log value as a result of deformation of the stem at the location of the wound.

One objective of this paper is to present some results from tree-wound surveys and inventories of the Nimitz Township and Dupuis Township thinning trials. The second objective is to estimate the volume and size of wood that could be removed through selective thinning. Two case studies located near Thunder Bay are examined with the aid of simulation: a site-class-1 stand (Raith) and a site-class-3 stand (Sackville Township). Finally, some data is given to show that thinning with the goal of producing logs for commodity-grade lumber is questionable and that any thinning should concentrate on increasing the value, quality and quantity of logs for specialty, high-value-added solid-wood products.

## METHODS

### Nimitz and Dupuis Thinning Trials

During the summer of 1988, wound surveys and preliminary inventories of the Nimitz and Dupuis thinning trials were made. The Nimitz thinning site is 51.8 ha in size. For the purposes of the study only 12 ha were included; these were located in Block 2 of Mattice and Riley (1975). The entire Dupuis thinned area (6.3 ha) and unthinned stands on its northern and southern sides were sampled. Core increment samples were also taken from wounded and non-wounded trees and analyzed in the laboratory for the presence of decay fungi. Detailed descriptions of the sample design and methodology can be found in McLaughlin (1989). During the summer of 1989, a detailed inventory of the areas studied during the summer of 1988 was made. A systematic line cruise was used, with 10.4 and 12.8% of the area sampled, respectively, for the Nimitz and Dupuis thinning trials. The data for wounding, height and outside-bark diameter at breast height (DBHOB) were analyzed to determine if there were any significant differences (t-test) between thinned and unthinned areas.

However, since the unthinned areas are not actual controls it cannot be said that any differences are the direct result of thinning and not, for example, the effect of site-quality factors. Data from Mattice and Riley (1975), Mattice and Curtis (1978), and Smith and Oerlemans (1988), and volume estimates for the study areas, were used to estimate the total volume yield for both sites.

### Sackville Township and Raith Study Sites

Two naturally regenerated, untended jack pine stands were studied in the Thunder Bay area. The Sackville

Township stand is 45 years old and is site class 3 (Plonski 1981), whereas the Raith study site is 40 years old and is site class 1.

To study various thinning strategies, stand maps were made. In both areas, for every tree taller than breast height, the x–y coordinates (to an accuracy of 1 dm) were determined and the following parameters recorded:

- species
- DBHOB
- outside-bark diameter at a height of 5.1 m
- tree height
- height to live crown
- crown class (dominant, codominant, intermediate, overtopped, understory, or dead)
- wounds present
- tree form class (normal tree, sweep of stem, tree leaning, top missing, insect damage, crooked stem, forked crown, stem bowed, sparse crown, poor tree vigor, wolf form [heavy branching])

At each study location, 12 adjacent 20- x 20-m plots were measured, for a total area of 0.48 ha. It must be pointed out that these case studies are not representative of all jack pine stands. Simulation models were used to analyze various thinning alternatives. The models were originally developed by Tymoshuk (1990), and were used to estimate the volume and characteristics of the material that could be removed through selective thinning in the areas. Reineke's Stand Density Index was employed for determining thinning weight (Spurr 1952, Husch et al. 1982, Day 1989). For a complete description of the methodology and models, refer to Tymoshuk (1990).

## RESULTS

### Nimitz and Dupuis Thinning Trials

Table 1 summarizes the inventory data for the thinning trials in Nimitz and Dupuis townships. The Nimitz Township site was thinned at age 45 and was 64 years old when measured. The Dupuis Township site was thinned at age 48 and was 64 years old when measured. There were highly significant differences between average heights in unthinned and thinned areas in both trials; trees in thinned areas were shorter. Smith and Oerlemans (1988) also mentioned the height difference at the Nimitz Township thinning trial, which they found to be a result of site quality rather than the effect of thinning. At the Nimitz Township thinning site there was a highly significant difference in DBHOB between the unthinned and thinned areas (trees in the thinned area had larger diameter), whereas there was no significant difference at the Dupuis Township site.

Table 1. Stand information for the thinning trials in Nimitz Township (after conventional shortwood strip thinning) and Dupuis Township (after strip thinning with a RW-30 tree-length harvester).

| | Avg. DBHOB (cm) | Avg. height (m) | Basal area ($m^2$/ha) | Stems/ ha |
|---|---|---|---|---|
| *Nimitz Twp* | | | | |
| Unthinned | 17.6 | 19.8 | 26.2 | 996 |
| Thinned | 19.2 | 18.7 | 24.0 | 761 |
| *Dupuis Twp* | | | | |
| Unthinned | 16.3 | 18.9 | 34.8 | 1,577 |
| Thinned | 16.7 | 17.5 | 24.7 | 1,075 |

Estimates of the total merchantable volume removed and available from the thinned and unthinned areas are presented in Table 2. There were mixed results in terms of total merchantable volume production: the Nimitz Township thinned area had significantly larger trees and the total merchantable volume to date is greater than in the unthinned area, whereas the highest volume production has been in the unthinned area in the Dupuis Township location. The data for the two townships are not comparable because of the large differences in stem size and stand density (i.e., different conditions). As well, it cannot be concluded that the differences between thinned and unthinned sites at each location are due solely to thinning because of the nature of the data.

If thinning can be assumed to have some effect, the "better" response at the Nimitz Township location may be a result of higher site quality. Based on current tree heights, the Nimitz Township area would be site class 1, whereas the Dupuis Township area would be site class 2 (Plonski 1981). Bella and de Franceschi (1974) studied jack pine 15 years after thinning at age 40. They found that the thinned stands on good sites (corresponding to Plonski's site class 1) exhibited 70% greater diameter increment than the control. Another factor may be that the original Dupuis Township site had a stand density of 2,914 stems/ha (Mattice and Curtis 1978), whereas it was 2,167 stems/ha at the Nimitz Township site (Smith and Oerlemans 1988). As a result, tree crowns at the Dupuis Township site may have been too small to respond to the increased growing space.

Table 3 summarizes the results of the 1988 wound survey. There are highly significant differences in the amount of wounding between thinned and unthinned areas at both study sites. The 1988 survey found the following percentages of trees with wounds: Nimitz un-

Table 2. Estimates of merchantable volume production for thinned and unthinned areas in the Nimitz and Dupuis townships sites.

| Year/ treatment | Volume ($m^3$/ha) (sob) | | | |
|---|---|---|---|---|
| | Nimitz Twp | | Dupuis Twp | |
| | Unthinned | Thinned | Unthinned | Thinned |
| *1970*[a] | | | | |
| Before thinning | 120 | 120 | – | – |
| After thinning | – | 67 | – | – |
| Volume removed | – | 53 | – | – |
| *1973*[b] | | | | |
| Before thinning | – | – | 123 | 123 |
| After thinning | – | – | – | 68 |
| Volume removed | – | – | – | 55 |
| *1989* | | | | |
| Estimated volume | 203 | 175 | 266 | 175 |
| Estimated total merch. vol. prod. to age 64 | 203 | 228 | 266 | 230 |
| Estimated annual increment | 3.2 | 3.6 | 4.2 | 3.6 |
| Avg. stem size ($m^3$) | 0.20 | 0.23 | 0.17 | 0.16 |

[a] Smith and Oerlemans (1988)
[b] Mattice and Curtis (1978)

Table 3. Results of wound surveys in thinned and unthinned stands in Nimitz and Dupuis Townships (McLaughlin 1989).

| Wound type[a] | Wound position[b] | | | | | |
|---|---|---|---|---|---|---|
| | Thinned area | | | Unthinned area | | |
| | low | high | total | low | high | total |
| *Dupuis Twp*[c] | | | | | | |
| Deep | 10 | 4 | 14 | 1 | 0 | 1 |
| Superficial | 50 | 30 | 80 | 6 | 5 | 11 |
| Total | 60 | 34 | 94 | 7 | 5 | 12 |
| % wounded[d] | | | (13.9%) | | | (3.6%) |
| *Nimitz Twp*[e] | | | | | | |
| Deep | 3 | 1 | 4 | 5 | 0 | 5 |
| Superficial | 49 | 34 | 83 | 17 | 14 | 31 |
| Total | 52 | 35 | 87 | 22 | 14 | 36 |
| % wounded[d] | | | (18.7%) | | | (7.5%) |

[a] deep = wounds that penetrated to the xylem, superficial = wounds that did not penetrate the cambium
[b] low = below breast height, high = above breast height
[c] 676 and 333 trees examined, respectively, on thinned and unthinned areas
[d] highly significant difference between thinned and unthinned areas
[e] 465 and 483 trees examined, respectively, on thinned and unthinned areas

thinned, 3.6%; Nimitz thinned, 13.9%; Dupuis unthinned, 7.5%; and Dupuis thinned, 18.7%. The wound survey done during the summer of 1989 revealed similar percentages of trees with wounds: Nimitz unthinned, 4.4%; Nimitz thinned, 19.3%; Dupuis unthinned, 6.6%; and Dupuis thinned, 18.8%. Pooling the data for both areas results in the following percentages of trees with wounds: thinned, 17.5% (n = 2295) vs. unthinned, 5.8% (n = 1540).

## Sackville Township and Raith Study Sites

The stand characteristics for the plots measured in Sackville Township and Raith before and after simulated selective thinning are presented in Table 4. Table 5 presents descriptions of the merchantable wood removed in the simulated thinnings. Thinning weight was calculated by means of Reineke's Stand Density Index. Since all trees taller than breast height (irrespective of DBHOB or dominance class) are included in the database, the thinning appears quite severe. However, 67 and 60% of the dominant and codominant stems were left after the Sackville and Raith simulated thinnings, respectively.

The two stands vary considerably. Tree DBHOB, height and volume are much lower at the Sackville Township site, and the tree crowns are small: i.e., it is questionable if trees will respond to the thinning. Because of their small diameter in relation to height, the trees would also be susceptible to snow and wind damage. The volume removed per hectare (including bark) is only 58 $m^3$(sob)/ha for trees with a DBHOB ≥ 10 cm. If utilization standards would accept a minimum top diameter ≥ 5 cm, irrespective of DBHOB, the volume removed would be approximately 100 $m^3$/ha, but because of the low stem size the harvesting cost would be high. Even if trees ≥ 10 cm DBHOB are removed, the harvesting cost per $m^3$ in the thinning is estimated to be at least 1.3 times that of clear-felling the stand

Table 4. Stand characteristics for the Sackville Township and Raith study sites.

| Characteristic | Sackville Township | Raith |
|---|---|---|
| Plot area (ha) | 0.48 | 0.48 |
| Year of measurement | 1989 | 1990 |
| Age at measurement | 45 | 40 |
| Site class (Plonski) | 3 | 1 |
| Average height (m) | 12.2 | 14.7 |
| *Original stand* | | |
| Stems/ha | 8,240 | 3,117 |
| Stems (≥ 10 cm DBHOB)/ha | 2,467 | 1,483 |
| Basal area (m²/ha) | 41 | 31 |
| Average DBHOB (cm) | 6.7 | 9.0 |
| Volume (trees ≥ 10 cm DBHOB) | | |
| m³(sob)/ha | 185 | 208 |
| m³(sob)/stem | 0.075 | 0.14 |
| *After simulated selective thinning* | | |
| Stems/ha | 2,115 | 619 |
| Basal area (m²/ha) | 17 | 14 |
| Average DBHOB (cm) | 10.5 | 16.4 |
| Volume (trees ≥ 10 cm DBHOB) | | |
| m³(sob)/ha | 126 | 113 |
| m³(sob)/stem | 0.08 | 0.19 |

Table 5. Descriptions of material removed by simulated selective thinning (trees that did not meet the utilization standards are not included).

| Characteristic[a] | Sackville Township | Raith |
|---|---|---|
| *No. of live stems removed/ha* | | |
| ≥ 10 cm DBHOB | 883 | 875 |
| min. dob | 2,488 | 1,240 |
| *Avg. vol. (m³) per live stem* | | |
| ≥ 10 cm DBHOB | 0.066 | 0.11 |
| min. dob | 0.04 | 0.08 |
| *Vol. live trees removed (m³(sob)/ha)* | | |
| ≥ 10 cm DBHOB | 58 | 95 |
| min. dob | 102 | 104 |
| *Vol. dead trees salvaged (m³(sob)/ha)* | | |
| ≥ 10 cm DBHOB | 3 | 3 |
| min. dob | 19 | 4 |

[a] min. dob = trees with a minimum outside-bark diameter ≥ 5 cm at a height of 5.1 m.

(assuming no road building) (Fig. 1). The above only takes into account tree size. The total volume removed from the logging chance, volume per hectare and primary transport distance are other factors influencing thinning costs.

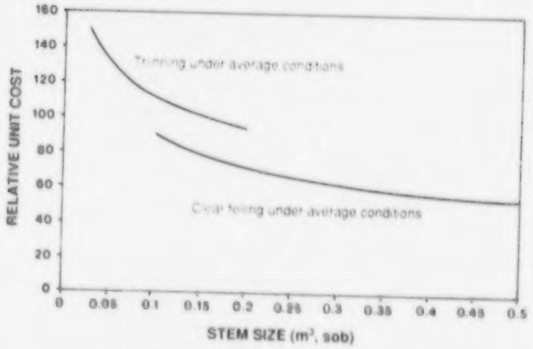

*Figure 1. Effect of tree size on relative logging cost, including cost of extraction, supervision, planning, machine moving, measurement and landing construction (Anon. 1983).*

At the Raith site DBHOB, height and crown size are much larger than those at Sackville Township. However, because there are fewer stems per hectare and site quality is better, there are more and larger branches. Self pruning of dead branches is also poor. This, in turn, would influence the quality of the material for high-value logs. Because of the larger crowns and diameters, the Raith stand should have the ability to respond to thinning and withstand snow damage better than the Sackville Township site. The volume available for removal is approximately 100 m³(sob)/ha (DBHOB ≥ 10 cm). This and the larger mean stem size of trees removed (0.11 m³(sob)/stem) would make commercial thinning more feasible. Based only on tree size, it is estimated that the cost of selective thinning would be at least 1.34 times that of clear-felling the stand (assuming no road building) (Fig. 1).

Only a small volume of dead material with a minimum DBHOB of 10 cm was salvaged in the simulated thinnings. The simulation on the Sackville Township data yielded 19 m³(sob)/ha of salvageable dead material when the minimum top diameter was specified at 5 cm, irrespective of DBHOB.

## DISCUSSION AND CONCLUSIONS

Based on the little information presented above, only broad generalizations can be made. Previous studies (Jameson 1956, Bella and de Franceschi 1974) and the data presented here indicate that site class has an important role in thinning response: i.e., higher site classes produce better results. Only at the Nimitz Township site was average DBHOB significantly greater in the thinned area (by 15%, or an average of 0.8%/year greater DBHOB growth). The total volume produced per hectare was higher in the thinned areas at the Nimitz Township site (12%, or an average of 0.65%/year), whereas at the Dupuis Township site it was considerably less than in unthinned areas. If it can be assumed that thinning had a major effect, then two factors may have resulted in the better thinning response at the Nimitz Township study site: better site quality, and a lower initial number of stems per hectare (thus, larger crowns). Pure strip thinning is questionable in terms of producing high-quality and high-value logs. Smith and Oerlemans (1988) also stated that selective thinning should be favored over pure strip thinning. Selective thinning with one-grip harvesters operating on machine trails at 20- to 30-m intervals is feasible and is standard practice in Finland and Sweden.

Unless care is taken, wounding can seriously reduce the value of the thinned stand. The high percentage of wounded trees in the thinned areas (17.5%, vs. 5.8% in the unthinned areas) emphasizes the need for good planning, supervision and training of employees. A high incidence of wounding can totally negate any quality gains expected as a result of thinning.

It appears that only site class 1 stands have sufficient tree size, volume per hectare, and potential response for commercial selective thinning to be feasible (i.e., to make a profit from harvesting and obtain some response to thinning). However, larger and more numerous limbs, combined with poor self pruning, may be problems when trying to grow high-quality sawlogs. Spacing at an early age (7 to 10 years) may yield stands with different conditions in terms of the feasibility of commercial thinning. There must also be a market available for small-diameter (5 to 10 cm) wood.

When considering thinning, the market must not be forgotten. The following calculations for 2 x 4 studs and Northern Bleached Softwood Kraft Pulp (NBSK) (both commodity products) show how poor the incentive is for thinning jack pine to grow logs for 2 x 4 studs under today's market conditions (Tables 6 and 7). The data are based on standard mill costs and have been cross-referenced with published data. There may be some discrepancies with individual mills, but the magnitude of the difference should be apparent.

Tables 6 and 7 indicate that a considerably higher price could be paid for the *same* piece of wood if it was

Table 6. Cost/revenue analysis of using wood from thinnings for SPF 2 x 4 studs.

| | | |
|---|---|---|
| Delivered price at retailer ($/m³) | $130.00 | |
| Less marketing and distribution costs | $25.00 | |
| Selling price at sawmill | $105.00 | $105.00 |
| m³ sawlogs/m³ sawn lumber | 2.30 | |
| % of sawmilling residue as marketable chips | 75.00 | |
| Price for chips ($/m³) | $40.00 | |
| Sales from chips | $39.00 | $39.00 |
| Net sales per m³ lumber | | $144.00 |
| Production costs per m³ lumber | | |
| - variable costs[a] | $30.00 | |
| - fixed costs[b] | $10.00 | |
| Total production cost per m³ lumber | $40.00 | |
| Capital costs per m³ lumber[c] | $15.00 | |
| Profit for sawmill per m³ lumber | $6.50 | |
| Total sawmill expenses per m³ lumber | $61.50 | $61.50 |
| Amount available for wood per m³ lumber | | $82.50 |
| Max. wood cost payable at mill gate per m³(sub)[d] | | $35.87 |
| Harvesting costs ($/m³(sub)) | | |
| long-distance transport | $13.00 | |
| loading | $2.25 | |
| slashing | $3.25 | |
| extraction | $9.65 | |
| roads | $2.50 | |
| planning, administration and overhead | $3.50 | |
| profit for logger | $5.00 | |
| Total harvesting cost ($/m³(sub)) | $39.15 | $39.15 |
| Residual wood value ($/m³(sub)) | | (-$3.28) |

[a] wood and lumber storage, sawing, kiln, steam, power, packaging, misc. goods, repairs, fringe benefits, etc.
[b] administration, rents, insurance, office, social costs, etc.
[c] interest, depreciation, taxes
[d] sub = scaled under bark

Table 7. Cost/revenue analysis of using wood from thinnings to produce NBSK pulp.

| | | |
|---|---|---|
| Delivered selling price per air-dry tonne (ADt) | $833.33 | |
| Marketing and distribution cost per ADt | $50.00 | |
| Selling price at pulp mill | $783.33 | $783.33 |
| $m^3$ sub Pulpwood/ADt NBSK pulp[a] | 5.90 | |
| Sales from byproducts per ADt | $25.00 | $25.00 |
| Net sales per ADt market pulp | $808.33 | |
| Production costs per ADt market pulp | | |
| - variable costs[b] | $175.00 | |
| - fixed costs[c] | $50.00 | |
| Total production cost per ADt | $225.00 | |
| Capital costs per ADt[d] | $100.00 | |
| Profit for pulpmill per ADt | $41.67 | |
| Total pulpmill expenses per ADt | $366.67 | $366.67 |
| Amount available for wood per ADt | | $441.67 |
| Maximum wood cost payable at mill gate per $m^3$(sub) | | $74.86 |
| Harvesting costs ($/$m^3$(sub)) | | |
| long-distance transport | $13.00 | |
| loading | $2.25 | |
| slashing | $3.25 | |
| extraction | $9.65 | |
| roads | $2.50 | |
| planning, administration and overhead | $3.50 | |
| profit for logger | $5.00 | |
| Total harvesting cost ($/$m^3$(sub)) | $39.15 | $39.15 |
| Residual wood value ($/$m^3$(sub)) | | $35.71 |

[a] sub = scaled under bark

[b] chemicals, processing, wages, wrapping wire, steam, electricity, packaging, misc. goods, repairs, fringe benefits, etc.

[c] administration, rents, insurance, office, social costs, etc.

[d] interest, depreciation, taxes

sent directly to a pulp mill. There is no financial incentive to grow sawlog material destined for commodity-grade products. The better alternative would be to grow jack pine under a short rotation for pulpwood.

A serious question to consider is whether jack pine should be reserved for extensive forest management and pulpwood production, whereas red pine (*Pinus resinosa* Ait.), for example, should be used for intensive forest management applications involving thinning and log production. This is because jack pine has a high growth rate during its juvenile stage, but growth drops off noticeably thereafter and any subsequent efforts to encourage growth after age 30 are less effective, since the period of greatest growth potential has been missed (Jameson 1956).

On the other hand, if log or stem quality and value can be increased considerably by thinning (i.e., to produce material for poles, specialty wood products, etc.), then thinning could be a viable alternative. This in turn would favor selective thinning. As a result of environmental sensitivity or multiple-use demands, which limit the scale of clearcuts in some areas, thinning may be necessary to obtain sufficient volumes of wood. Also, as more information and experience with jack pine growth response after spacing becomes available, thinning may become more attractive.

At this point it would appear that only site class 1 stands show any promise for commercial thinning, due to a possible increase in tree size, a greater volume removed per hectare, and lower susceptibility to snow and wind damage. A heavy thinning or shelterwood type of cut to release understory black spruce (*Picea mariana* [Mill.] B.S.P.) could also be a silvicultural alternative. For example, this was the case at both the Sackville Township and Raith sites, where there was a considerable black spruce component in the understory. As mentioned above, another alternative is to space jack pine at an early age and just let it grow naturally for a pulpwood harvest. It is apparent there are many unanswered questions. Only the surface of this issue has been scratched and there is much work required to answer the above questions.

## LITERATURE CITED

Anon., 1983. Leimikon suunnittelu. Metsäteho, Metsätehon Opas., Helsinki, Finland. 36 p.

Bella, I.E. and de Franceschi, J.P. 1974. Commercial thinning improves growth of jack pine. Dep. Environ., Can. For. Serv., Edmonton, Alta., Inf. Rep. NOR-X-112. 23 p.

Day, R.J. 1989. A manual of silviculture. Lakehead Univ., Sch. For., Thunder Bay, Ont. 311 p.

Husch, B., Miller, C.I. and Beers, T.W. 1982. Forest mensuration. John Wiley and Sons, Inc., Toronto, Ont. 402 p.

Jameson, J.S. 1956. Strip and spaced thinning in overstocked jack pine and black spruce stands. Dep. Northern Affairs and Nat. Resour., For. Br., For. Res. Div., Ottawa, Ont. Project manuscript 134. 9 p.

Mattice, C.R. and Curtis, F.W. 1978. Commercial strip thinning with a tree-length harvester. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. 0-X-272. 17 p.

Mattice, C.R. and Riley, L.F. 1975. Commercial strip thinning in a 45-year-old jack pine stand. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. 0-X-233. 15 p.

McLaughlin, J.A. 1989. Wounding and decay in two commercially thinned jack pine stands in Northern Ontario. Lakehead Univ., Sch. For., Thunder Bay, Ont. Undergrad. Thesis. 68 p.

Plonski, W.L. 1981. Normal yield tables (metric). Ont. Min. Nat. Resour., For. Resour. Group, Toronto, Ont. 40 p.

Smith, C.R. and Oerlemans, W.J.A.M. 1988. Ten-year growth response and financial evaluation of commercial strip thinning of jack pine: a case study. Gov't of Can., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. 0-X-396. 25 p.

Spurr, S.H. 1952. Forest inventory. Roland Press Co., New York, N.Y. 476 p.

Tymoshuk, J.A. 1990. The use of computer simulation for studying thinning on jack pine. Lakehead Univ., Sch. For., Undergrad. Thesis. 71 p.

# EVALUATING THE INFLUENCE OF SPACING AND THINNING ON WOOD QUALITY

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## ABSTRACT

Stocking-control treatments add to wood costs. If these costs cannot be recovered through greater merchantable volume or improved quality, the treatments will not be economically viable in eastern Canada, where wood costs are already above the world average. Since it is difficult to predict the characteristics that will be considered valuable at the end of Canada's long rotations, forest managers have emphasized improved volume yields. However, many economists believe the future of the Canadian forest products industry lies with specialty or value-added products, for which quality is of greater importance. To improve the quality of our managed resource, attention should be focused where there is the greatest potential gain. Tremendous quality gains could be made in eastern Canadian softwood stands by improving stem quality. The potential for improvement in stem quality appears to outweigh the potential for either positive or negative changes in basic wood properties as a result of decreased stand density. Assessments of stem quality should be included in existing silvicultural experiments to determine when stem defects are most likely to develop during a stand's life cycle and whether the proportion of deformed stems can be reduced through improved tending methods.

## RÉSUMÉ

La surveillance du matériel relatif augmente les coûts du bois. Si l'on ne peut récupérer ces coûts grâce à un volume marchand plus important ou à une qualité améliorée, les traitements ne seront pas rentables dans l'est du Canada, où les coûts du bois dépassent déjà la moyenne mondiale. Puisqu'il est difficile de prévoir quelles seront les caractéristiques jugées importantes à la fin des longues révolutions au Canada, les aménagistes forestiers ont mis l'accent sur l'accroissement des volumes de production. Toutefois, selon bon nombre d'économistes, l'avenir de l'industrie des produits forestiers canadiens reposera sur des produits spéciaux ou à valeur ajoutée, pour lesquels la qualité importe avant tout, plutôt que sur des produits de base, pour lesquels le volume de production est crucial. Si l'on déploie des efforts pour améliorer la qualité de nos forêts aménagées, ce sont les scénarios offrant le plus grand potentiel de gains qui doivent être le point de mire. Dans les peuplements de conifères de l'Est canadien, on pourrait accroître, de façon fort marquée, la qualité des arbres en améliorant celle des tiges. Des changements positifs ou négatifs des propriétés du bois pourraient être entraînés par la diminution de la densité de peuplement. On avance l'hypothèse selon laquelle on peut déterminer, au stade de l'évaluation de la qualité des peuplements, à quel moment du cycle biologique de ceux-ci, des anomalies des tiges risquent le plus de se produire et si l'on peut réduire le pourcentage élevé de tiges de forme irrégulière au moyen de soins culturaux améliorés.

## INTRODUCTION

Stocking control, whether by initial spacing, subsequent cleaning and thinning of plantations, or thinning in natural stands, is expensive. In eastern Canada, wood costs are already higher than the world average (Simons 1988), and silvicultural costs must be justified either by substantially improved volume production on sites close to mills or by significant improvements in quality. Simply managing stands to fill projected gaps in the future wood supply is a dangerous practice unless (1) the managed volume can be delivered at a lower cost than that of our competitors in world markets (Sedjo 1983, Brett-Davies 1987, Barbour and Kellogg 1990) or (2) a level of quality that will allow the manufacture of products that are clearly superior to those available elsewhere can be ensured (Barbour and Kellogg 1990).

Forest managers commonly focus on improved volume production to justify silvicultural costs because the effects of silvicultural treatments on value are difficult to predict. This is particularly true in eastern Canada, where softwood logs, with the exception of red pine (*Pinus resinosa* Ait.) and white pine (*P. strobus* L.), are not graded. It is also difficult to predict the quality characteristics that will be required in 40 to 60 years, since long-range forecasts of product demand or technological advances are inherently unreliable. This paper discusses some general aspects of the potential for improving the quality and value of the resource through stocking control.

## FUTURE MARKETS

Although long-term projections are hazy, some trends have been identified. Commodity markets, Canada's current mainstay, are projected to grow at a slower rate than that experienced over the past half century. For example, Schuler (1987) forecasts that the annual growth in demand for solid wood products will drop from the historical 1.8% per year to 1.2% per year during the next two decades. This climate will make it difficult for small to medium lumber producers and older, less-efficient pulp and paper mills that depend solely on commodity grades, to survive periods of prolonged economic downturn (Simons 1988).

These projections suggest that a more assured road to prosperity for the Canadian forest products industry is through increased production of value-added or specialty products and decreased reliance on commodity products (Anon. 1990, Mater 1990, Meil 1990, Schuler and Meil 1991). Most specialty products require high-quality raw material, so there will be renewed interest in wood and tree quality as Canadian manufacturers increase emphasis on these products.

## WHAT IS QUALITY?

When considering the quality of a managed resource, it is important to recognize the factors that create or detract from quality and how they are controlled. Without this information, the word "quality" is meaningless to forest managers because it cannot be translated into management objectives. There are properties for coniferous woods that have always been recognized as "good", and a corresponding set recognized as "bad". Maintenance of relative density near the population mean for the species, a high level of dimensional stability, large sapwood area (for treatability and pulpability), low resin content, long fibers, good mechanical properties (both of wood and fibers), high alpha-cellulose content, straight grain, small (or tight) knots, sound wood, easily removable bark and low scleroid content are considered positive. Large knots and high knot volumes, high bark volumes, spiral grain, high microfibril angle, low permeability, reaction wood, high lignin content, crooked or sweepy stems, and excessive taper are negative (Christie 1987, Barbour and Kellogg 1990).

Understanding how changes in these properties alter the value of the managed resource allows an assessment of the relative economic merits of different silvicultural treatments. Kellogg (1989), Lackner and Foslie (1988), Eversten (1987), Kininmonth (1987), James (1983) and others have shown that it is possible to produce species-specific models that can be used to predict end-product value for known site characteristics and silvicultural treatments. These types of models could presumably also be used to assess the value of existing natural or managed stands if the stand history is known or can be deduced.

Models with this level of sophistication do not presently exist for any boreal species, but less refined methods can be used. Areas in which improvement is necessary or maintenance of existing quality levels is essential can be identified by considering the properties of the existing resource and their influence on conversion processes. By examining how these properties change (e.g., in response to wider spacing), it will be possible to speculate on shifts that might occur in the quality of the managed resource.

Within limits (Garner 1987), the larger, more uniform stems produced in thinned stands are less expensive to harvest, transport, handle and process than the smaller, more variable stems found in natural stands (Franklin 1987, Heidersdorf 1987, Sinclair 1987). Stands with a higher proportion of medium and large stems also allow greater flexibility in the production of a wider variety of solid products (Moul 1987).

Size is not, however, the only criterion that determines the quality and value of a tree. Basic wood properties such as relative density, fiber length, extractives content, and chemical composition of the cell walls all influence the types and quality of products that can be manufactured from a tree. These are, in theory, sensitive to the magnitude of physiological activity (c.f. Larson 1962, 1969) and, therefore, at least partially controlled by available growing space. Barbour (1990) has shown that rapidly grown black spruce (*Picea mariana* [Mill.] B.S.P.) and jack pine (*Pinus banksiana* Lamb.) trees tend to have relative densities about 6% lower than the species average. This means that a 6% increase in the volume of pulpwood produced from a managed resource would be required simply to adjust for the change in relative density. Lower relative densities will also have a negative impact on the strength and stiffness of lumber, which could reduce the yield of such value-added products as machine stress-rated (MSR) lumber.

## HOW CAN QUALITY BE IMPROVED?

After thinning, the morphology of residual trees (e.g., taper, branch size and stem straightness) frequently deteriorates as a result of decreased competition (Larson 1963). However, in eastern Canada, thinning holds the potential for improving stem morphology merely by removing damaged and deformed stems and preventing damage to straight residual stems. Available data suggests that this outweighs the potential for altering quality through either positive or negative changes in basic wood properties resulting from silvicultural treatments.

Corneau (1989) conducted a study of the morphology of 4,000 logs from seven sawmills in northern Ontario and Quebec. Results from this study are shown in Table 1. Half of the logs in the sample contained sweep and, depending on the size of the log, between 10 and 20% had crook. As log size decreased, the intensity of crook became greater.

Table 1. Occurrence of sweep and crook, by log size[a].

| Log characteristic | Total sample (%) | Log size[b] Small (%) | Medium (%) | Large (%) |
|---|---|---|---|---|
| Straight logs | 19.3 | 16.2 | 19.5 | 30.3 |
| Logs with crook | 17.1 | 21.3 | 14.5 | 8.8 |
| Logs with sweep | 51.5 | 48.4 | 54.0 | 55.9 |
| Logs with sweep and crook | 12.1 | 14.1 | 12.0 | 5.0 |

[a] from Corneau (1989)

[b] small logs = top diameter classes 8 to 14 cm, medium logs = top diameter classes 16 to 20 cm, large logs = top diameter classes > 22 cm.

The impact of stem defects on value and product quality is very important. Crooked or sweepy trees and logs increase harvesting and transportation costs (Franklin 1987). In eastern Canada, harvesting typically represents 40 to 60% of the total delivered wood cost (Heidersdorf 1987) and hauling can account for 30 to 50% of the delivered cost (Franklin 1987). Pulp yields from deformed trees are lower and the pulps have inferior properties compared with pulps from straight trees (Blair et al. 1974, Zobel 1977). In addition, lumber recoveries from crooked logs range from 10 to 30% lower than those of straight stems of similar diameters (Dobie and Middleton 1980, Ffolliott et al. 1983, Middleton et al. 1989).

Several studies have considered changes in stem form in immature jack pine stands as a result of increased spacing (Ralston 1953; Guilkey and Westing 1956; Godman and Cooley 1970; Bella and De Francheschi 1974, 1980; Janas and Brand 1988). In each of these studies, spacings wider than about 3 m resulted in poorly formed trees. Bella and De Francheschi (1974) found that stem deformities increased with increasing spacing. In plantations spaced at 1.2 m, approximately 10% of the stems had some type of defect (e.g., forks, crooks, excessive sweep); at 3.3 m, 20% of the stems had one or more defects.

Although the frequency of stem defects may at first seem low compared with that in natural stands (Table 1), it must be remembered that the types of defects catalogued by Bella and De Franceschi (1974, 1980) were typically much more severe than those recorded by Corneau (1989). Corneau used exacting procedures to identify all stem deviations greater than one centimetre in logs, whereas Bella and De Franceschi recorded only those defects that were obvious in standing trees. This implies that the level of stem deformities in plantations is probably much higher than in natural stands.

Data for thinned stands is even more sketchy than for plantations. Janas and Brand (1988) evaluated stem form in a naturally regenerated jack pine stand that initially contained more than 10,000 stems/ha, as well as in plantations established at 2.1- and 4.3-m spacings. They felt that the best stem quality resulted from natural regeneration or direct seeding followed by precommercial thinning. This method reduces stand-establishment costs, allows the best stems to be selected during thinning, and provides for the use of genetically improved seed as it becomes available. Delaying thinning until after crown closure minimizes branch size in the lower stem, further improving stem quality.

Uncertainty about stem quality in plantations and after thinning demands that this subject be given high priority in future research efforts. Reliable means need to be developed to assess stem quality in standing trees. These should then be applied in a consistent manner in all future remeasurements of spacing trials, progeny trials or family tests. A baseline also needs to be established for natural stands of various ages and on different site types so data gathered for managed stands can be properly evaluated and compared.

The jack pine stands examined by Janas and Brand (1988) and Bella and De Franceschi (1974, 1980) were young, and no data exist for white spruce (*Picea glauca* [Moench] Voss), black spruce or balsam fir (*Abies balsamea* [L.] Mill.). More data needs to be collected for all of these species, using older material wherever possible. Research should focus on both plantations and thinned natural stands to determine the causes of stem deformities, as well as the period during the life cycle of a stand when they are most likely to occur. More information is also needed on the costs of poor stem form in terms of pulp and lumber recovery and quality.

For example, if a fire-origin jack pine stand is precommercially thinned at 2 to 5 m in height and all deformed stems are removed, will the proportion of deformed stems at rotation age be improved over that found in similar natural stands? Are certain spacings better than others for plantations or thinned stands? Should young stands be sheltered from prevailing winds, or should we avoid management investments on certain site types because of the potential for damage from heavy snow or ice loads? The answers to these questions could be found by examining existing natural stands with various stocking densities, on different site types and with varying degrees of exposure, as well as by examining existing spacing trials, progeny tests, thinning experiments, etc.

## CONCLUSIONS

As the Canadian forest industry moves toward the production of more specialized products, it is appropriate to emphasize the quality of the resource, since quality standards for these products are more rigorous than for commodities such as pulp. There is great potential for improvement in the quality of the existing softwood resource in eastern Canada. Significant stem-quality improvements can be made by removing damaged stems during thinning operations. More research is needed, however, to determine when stem defects develop during the life cycle of a stand and how they can be controlled by silvicultural treatments.

## LITERATURE CITED

Anon. 1990. A study of the "value added to one cubic meter of roundwood in New Brunswick." Prepared for Gov't of New Brunswick, Dep. Commerce and Technol. ADI Ltd., Fredericton, N.B. 42 p.

Barbour, R.J. 1990. Wood quality: what it is and how it is influenced by forest management practices. p. 145–168 *in* A.J. Willcocks, W.D. Baker, L. Sumi and W. Carmean, *Ed.* Tools for site specific silviculture in northwestern Ontario. Proc. Workshop held in Thunder Bay, Ontario, 19–20 April 1989. Ont. Min. Nat. Resour., Northwestern Ont. For. Tech. Devel. Unit, Thunder Bay, Ontario. Tech. Workshop Rep. No. 3.

Barbour, R.J. and Kellogg, R.M. 1990. Forest management and end-product quality: a Canadian perspective. Can. J. For. Res. 20:405–414.

Bella, I.E. and De Franceschi, J.P. 1974. Early results of spacing studies of three indigenous conifers in Manitoba. Dep. Environ., Can. For. Serv., Edmonton, Alta. Rep. NOR–X–113.

Bella, I.E. and De Franceschi, J.P. 1980. Spacing effects 15 years after planting three conifers in Manitoba. Dep. Environ., Can. For. Serv., Edmonton, Alta. Inf. Rep. NOR–X–223.

Blair, R.L., Zobel, B.J., Franklin, E.C., Djerf, A.C. and Mendel, J.M. 1974. The effect of tree form and rust infection on wood and pulp properties of loblolly pine. Tappi 57(7):46–50.

Brett-Davies, A.N. 1987. Canada's future wood harvest. p. 5.1–5.2 *in* T. Rotherham and J.V. Hatton, *Ed.* Forest crop planning. A corporate approach to strategic planning of forest fibres, trees and stands to meet market needs, twenty-two expert views. Can. Pulp and Paper Assoc., Pointe Claire, Que.

Christie, D. 1987. Pulp and paper technical trends. p. 22.1–22.2 *in* T. Rotherham and J.V. Hatton, *Ed.* Forest crop planning. A corporate approach to strategic planning of forest fibres, trees and stands to meet market needs, twenty-two expert views. Can. Pulp and Paper Assoc., Pointe Claire, Que.

Corneau, Y. 1989. Occurrence and severity of sweep. FORINTEK Can. Corp., Ottawa, Ont. Internal Rep. No. 37–43–K–420.

Dobie, J. and Middleton, G.R. 1980. Lumber yields from sweepy lodgepole pine. For. Chron. 56(2):66–67.

Eversten, J.A., *Coordinator*. 1987. Lodgepole pine taskforce. EOLAS, the Irish Sci. and Technol. Agency, Dublin, Ireland. Rep. No. 2. 128 p.

Ffolliott, P.F., Rasmussen, W.O. and Gottfried, G.J. 1983. Stem characteristic changes affect long-term planning for timber resource utilization. For. Prod. J. 33(2): 57–60.

Franklin, G. 1987. Crop planning for improved wood transportation cost and efficiency. p. 20.1–20.2 *in* T. Rotherham and J.V. Hatton, *Ed.* Forest crop planning. A corporate approach to strategic planning of forest fibres, trees and stands to meet market needs, twenty-two expert views. Can. Pulp and Paper Assoc., Pointe Claire, Que.

Garner, G.J. 1987. Creating a forest that's an asset: a harvesting perspective. p. 9.1–9.3 *in* T. Rotherham and

J.V. Hatton, *Ed.* Forest crop planning. A corporate approach to strategic planning of forest fibres, trees and stands to meet market needs, twenty-two expert views. Can. Pulp and Paper Assoc., Pointe Claire, Que.

Godman, R.M. and Cooley, J.H. 1970. Effect of initial spacing on the development of young jack pine growth and yield. Michigan Academician 2(4):107–111.

Guilkey, P.C. and Westing, A.H. 1956. Effects of initial spacing on the development of young jack pine in northern lower Michigan. Michigan Acad. Sci. Arts and Letters 51:45–50.

Heidersdorf, E. 1987. Crop planning for harvesting efficiency. p. 14.1–14.2 *in* T. Rotherham and J.V. Hatton, *Ed.* Forest crop planning. A corporate approach to strategic planning of forest fibres, trees and stands to meet market needs, twenty-two expert views. Can. Pulp and Paper Assoc., Pointe Claire, Que.

James, R.N. 1983. The prediction of growth and wood quality parameters for plantation grown *Pinus radiata* D. Don in New Zealand. Oxford University, U.K. Ph.D. Dissertation.

Janas, P.S. and Brand, D.G. 1988. Comparative growth and development of planted and natural stands of jack pine. For. Chron. 64(4):320–328.

Kellogg, R.M., *Compiler*. 1989. Second growth Douglas-fir: its management and conversion for value. A report of the Douglas-fir task force. FORINTEK Can. Corp., Vancouver, B.C. Special Publ. No. SP–32.

Kininmonth, J.A., *Compiler*. 1987. Proceedings of the conversion planning conference, Rotorua, 8–11 April 1986. New Zealand For. Serv. Res. Inst., Rotorua, New Zealand. Bull. No. 128.

Lackner, R. and Foslie, M. 1988. Gran fra Vestlandet Styrke og sortering [Spruce from western Norway, strength, stiffness and grading.] Norwegian Inst. Wood Technol., Oslo, Norway. Rep. No. 74.

Larson, P.R. 1962. A biological approach to wood quality. Tappi 45(6):443–448.

Larson. P.R. 1963. Stem form development of forest trees. For. Sci. Monograph No. 5. 42 p.

Larson, P.R. 1969. Wood formation and the concept of wood quality. Yale Univ., Sch. For., New Haven, Conn. Bull. No. 74. 54 p.

Mater, J. 1990. 'Value-added' products: key to competition. For. Ind. 117(2):20–22.

Meil, J.K. 1990. Value-added trends and technology feasibility limits in Canadian softwood lumber producing regions. For. Chron. 66(1):45–50.

Middleton, G.R., Carter, R.E., Munro, B.D. and Mackay, J.F.G. 1989. Losses in timber values associated with distorted growth in immature Douglas-fir. Gov't of Can., Can. For. Serv., Victoria, B.C. and Province of British Columbia. Canada/BC Econ. and Reg. Devel. Agreement, FRDA Rep. 050. 20 p.

Moul, A.A. 1987. Lumber production technology. p. 12.1–12.2 *in* T. Rotherham and J.V. Hatton, *Ed.* Forest crop planning. A corporate approach to strategic planning of forest fibres, trees and stands to meet market needs, twenty-two expert views. Can. Pulp and Paper Assoc., Pointe Claire, Que.

Ralston, R.A. 1953. Some effects of spacing on jack pine development in lower Michigan after twenty-five years. Michigan Acad. Sci. Arts and Letters 38: 137–143.

Schuler, A.T. 1987. Selecting a competitive strategy for the future. p. 19.1–19.3 *in* T. Rotherham and J.V. Hatton, *Ed.* Forest crop planning. A corporate approach to strategic planning of forest fibres, trees and stands to meet market needs, twenty-two expert views. Can. Pulp and Paper Assoc., Pointe Claire, Que.

Schuler, A.T. and Meil, J.K. 1991. Markets, products and technology in the 21st century — a Canadian solid wood products perspective. For. Chron. 67(6). (in press)

Sedjo, R.A. 1983. The comparative economics of plantation forestry: a global assessment. Resources for the future. John Hopkins Univ. Press, Baltimore, Md.

Simons, A.H. 1988. Canada's forest industry, the next twenty years: cost projections. Prepared for Gov't of Can., Can. For. Serv., Econ. Br., Ottawa, Ont. 41 p.

Sinclair, A.W.J. 1987. Consider harvesting and transportation systems when forest crop planning. p. 15.1–15.2 *in* T. Rotherham and J.V. Hatton, *Ed.* Forest crop planning. A corporate approach to strategic planning of forest fibres, trees and stands to meet market needs, twenty-two expert views. Can. Pulp and Paper Assoc., Pointe Claire, Que.

Zobel, B.J. 1977. Increasing southern pine timber production through tree improvement. Southern J. Appl. For. 1(1):3–10.

# CROP PLANNING AND THE IMPORTANCE OF PRECOMMERCIAL THINNING

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## ABSTRACT

In applying crop-planning principles to a forest with a unique structure, unique harvesting and silvicultural strategies are required. For part of one forest in Thunder Bay District, for which a pulpwood and sawlog shortage is expected in 45 years, precommercial thinning of existing immature stands rather than planting can provide future wood at the highest economic efficiency. Precommercial thinning of existing 15- to 20-year-old stands should produce operable stands within 45 years, whereas planting will likely require more than 50 years. Moreover, the cost of precommercial thinning averages $400/ha, versus more than $1000/ha for planting.

The crop-planning process solves forest management problems in a manner consistent with the forest's dynamic structure. In the case of the Thunder Bay forest, crop planning challenges the exclusive application of planting as the recommended silvicultural strategy.

## RÉSUMÉ

Pour appliquer des principes de planification de la récolte à une forêt dont la structure est unique, il faut des stratégies sylvicoles et d'exploitation spéciales. Dans une partie d'une forêt située dans le district de Thunder Bay, où on prévoit une pénurie de bois de pâte et de grumes de sciage d'ici 45 ans, une éclaircie précommerciale des peuplements actuels n'ayant pas encore atteint la maturité, plutôt que la plantation d'arbres, constitue le moyen le plus rentable d'assurer un approvisionnement futur en bois. Une éclaircie précommerciale des peuplements actuels âgés de 15 à 20 ans devrait produire des peuplements exploitables d'ici 45 ans, tandis que la plantation d'arbres ne donnerait probablement les mêmes résultats qu'au bout de plus de 50 ans. De plus, le coût des opérations d'éclaircie précommerciale atteint en moyenne 400 $/ha, tandis que les coûts de la plantation excède 1 000 $/ha.

La planification des récoltes permet de résoudre des problèmes d'aménagement forestier sans nuire à la structure dynamique d'une forêt. Dans le cas de la forêt de Thunder Bay, cette méthode, plutôt que le recours exclusif à la plantation, semble tout indiquée comme stratégie sylvicole.

## INTRODUCTION

A major challenge for every forest manager is to manipulate the structure and development of a particular forest so it will meet the current and future demands placed on it. Preparing a realistic management plan for a forest is a complex decision-making process that must determine which strategies will best satisfy demands for flows of benefits from the forest. For most types of forest benefits, especially timber, this decision-making process may be called crop planning, as described by Willcocks et al. (1990). In this paper, I will briefly outline the process and the results of one crop planning exercise in the Thunder Bay District.

## CROP PLANNING

In a nutshell, crop planning matches forest management objectives with the levels of harvesting and silviculture required to meet the stated objectives. One should know how a 2-m spacing or precommercial thinning will affect sustainable yield and the quality of product produced.

A manager using a forest analysis simulation such as FORMAN (Wang et al. 1987) first defines the nature of the forest management problem (Fig. 1).

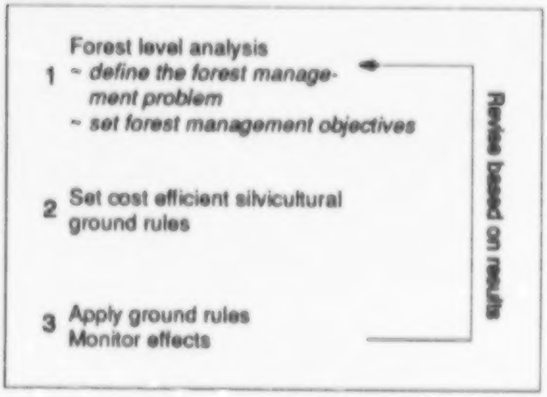
Forest level analysis
1
~ define the forest management problem
~ set forest management objectives
2
Set cost efficient silvicultural ground rules
3
Apply ground rules
Monitor effects
Revise based on results

*Figure 1. Outline of the crop-planning process.*

The harvest and silvicultural solutions that will solve these problems are then determined. Next, the most cost-efficient ground rules that will implement the required forest management objectives are proposed. Finally, the manager monitors the results at the field level and, as with piloting a ship, adjusts the course of the forest management effort as new information is received.

For parts of one forest in Thunder Bay District with an apparent pulpwood shortage in 45 years, crop-planning strategies were applied. The parts of the forest considered were black spruce (*Picea mariana* [Mill.] B.S.P.) Site Class 1a stands, which comprise 32% of the forest in the overmature age classes. When the forest was analyzed, a yield of 97,000 m$^3$/year could be sustained without silviculture. A yield of 110,000 m$^3$/year was required to meet forest-management goals.

To achieve the required sustainable yield, planting at two spacing regimes and precommercial thinning were tried. The precommercial thinning option proved to be significantly cheaper and provided more benefits than both planting options (Table 1). The values in Table 1 are not something magical, produced by the black box called FORMAN. Precommercial thinning only costs $200 to $400/ha, whereas planting costs more than $1000/ha. Fortunately, there is an ample supply of young, thinnable stands to allow us to take advantage of this economical treatment.

Table 1. Silvicultural solutions to produce 110,000 m$^3$/year of pulpwood.

| Option | Annual cost ($1000) | Benefit/Cost |
|---|---|---|
| Plant at 2.0-m spacing | 240 | 8.4 |
| Plant at 2.5-m spacing | 211 | 9.5 |
| Precommercial thinning | 159 | 12.7 |

A key assumption in the above analysis is that the value of a cubic metre of fiber produced by all the options is the same. However, R.J. Barbour (Research Scientist, FORINTEK, Ottawa, personal communication) has suggested that fiber quality can vary as a result of different silvicultural options. This could modify the results in Table 1. The crop-planning process can also compare options based on varying fiber quality.

Very high benefit/cost ratios are indicated in Table 1. These ratios are based on gross provincial values added to the economy and not on stumpage or net profit to a company. For each sustainable cubic meter of pulpwood produced by silvicultural or other strategies, $155 of revenue is contributed to the provincial economy ($95 for sawlogs). These numbers were developed by Willcocks et al. (1990) and will likely vary significantly with different management costs. The benefit/cost ratio is defined as the total revenue gained per year as a result of silvicultural efforts (i.e., additional wood grown x gross provincial values) divided by annual silvicultural costs. The benefit/cost ratio is based on current silvicultural input, which is an allowable-cut effect. The allowable-cut effect is defined as the amount of sustainable yield that can be supported based on silvicultural input at the present time (Willcocks et al. 1990). For example, if the sustainable yield of a forest is 500,000 m$^3$/year with no silvicultural input, any extra sustainable yield resulting from silviculture could be harvested immediately.

Once the most efficient silvicultural strategies have been determined for the required sustainable yield, the manager then determines if even more sustainable yield could be squeezed out of the resource (Table 2). By applying more silvicultural inputs, such as planting and thinning stands, planting at 3-m spacing will produce the maximum sustainable yield. However, using the thinning option produces a slightly lower maximum sustainable yield, but at a higher economic efficiency (Table 2).

Table 2. Maximum sustainable harvest (pulpwood) as a result of four treatments.

| Option | Annual cost ($1000) | Sustainable harvest (1000 m$^3$/yr) | Benefit/Cost |
|---|---|---|---|
| Plant at 2.0 m | 480 | 115 | 6.8 |
| Plant at 2.5 m | 437 | 120 | 8.5 |
| Plant at 3.0 m | 505 | 125 | 8.6 |
| Precommercial thinning | 319 | 120 | 11.2 |

What would happen if this same forest produced 95,000 $m^3$/year of sawlogs? Analysis shows that only 75,000 $m^3$/year can be sustained without silviculture. Unlimited planting can only increase the yield to 80,000 $m^3$/year. Table 3 shows that a combination of planting and thinning will produce the required yield of 95,000 $m^3$/year. Again, the wider-spaced plantations are the most cost efficient because they are operable earlier.

Table 3. Silvicultural solutions required to produce 95,000 $m^3$/year of sawlogs.

| Option | Annual cost ($1000) | Benefit/ Cost[a] |
|---|---|---|
| Planting only | doesn't work | – |
| Plant at 2.0 m, thin | 291 | 4.08 |
| Plant at 2.5 m, thin | 165 | 6.35 |
| Plant at 3.0 m, thin | 133 | 6.96 |

[a] first 15 years

Again, the little black-box simulator produces the answer, but is the answer logical? If you have a supply problem in 35 years, as in the case of this forest, thinning existing natural 10- to 20-year-old stands would provide operable stands in 15 years, whereas new plantations would provide wood in 50 to 70 years. Planting takes too long to produce the required results.

In both examples, thinning worked largely because of the large percentage of thinnable stands available. In other forests with few thinnable stands, or if natural regeneration was not an option, other silvicultural options such as planting may prove to be a better choice. The key is to know your forest and be flexible and innovative when attempting to solve your forest-management problem.

In summary, silvicultural strategies are tied closely to the uniqueness of the forest and the products required. Precommercial thinning can be a very cost-efficient treatment for providing wood in forests with an impending wood shortage. The multi-million dollar question is: Why isn't precommercial thinning widespread in Northern Ontario? Do we have a planting mindset?

## LITERATURE CITED

Wang, E.T., Erdle, T. and Roussell, T. 1987. FORMAN wood supply model user manual. Version 2.1. New Brunswick Dep. Nat. Resour., Fredericton. Mimeo. 61 p.

Willcocks, A.J., Bell, F.W., Williams, J. and Duinker, P.N. 1990. A crop-planning process for Northwestern Ontario Forests. Ont. Min. Nat. Resour., Northwestern Ont. Tech. Devel. Unit, Thunder Bay, Ont. Tech. Rep. No. 30. 159 p.

# THE EFFECT OF THINNING ON THE YIELD AND ECONOMY OF GROWING SOFTWOOD STANDS IN FINLAND

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## ABSTRACT

Thinning has always played an important role in satisfying the needs of the forest industry in Finland. A regularly thinned and regenerated stand is profitable because natural mortality is avoided and early revenues and faster diameter growth are obtained.

Prerequisites for economical thinning are intensive thinning of sapling stands, using appropriate harvesting equipment, and the utilization of small-diameter wood by the forest industry. On Finland's fairly easy terrain, the shortwood harvesting method has been shown to be effective for both thinning and clearcutting.

## RÉSUMÉ

En Finlande, les opérations d'éclaircie ont toujours joué un rôle d'importance en ce qui a trait aux besoins de l'industrie forestière. Il est profitable d'éclaircir et de régénérer régulièrement les peuplements, car on évite ainsi la mort naturelle des arbres, on touche plus rapidement des revenus et on accélère l'accroissement du diamètre des arbres.

Pour que les opérations d'éclaircie soient rentables, il faut procéder à des éclaircies intensives des peuplements de gaules, au moyen d'engins d'abattage appropriés, et l'industrie forestière doit utiliser des arbres de plus petit diamètre. Sur les terres relativement peu accidentées de la Finlande, la méthode d'exploitation en bois court s'est révélée efficace tant pour les opérations d'éclaircie que pour la coupe à blanc.

## INTRODUCTION

Finland is a densely forested country in northern Europe located between 60° and 70° north latitude. The mean annual temperature in Helsinki is +5° (1931–1960) and is +0.5° in Rovaniemi, in Finnish Lapland. The average annual rainfall is 500 to 700 mm and the effective temperature sum is 1300 degree-days in southern and 500 to 800 degree-days in northern Finland. About 65% of the forest area is privately owned (300,000 owners), 25% is state owned and 10% is owned by companies.

Finland's resources have been inventoried eight times since the early 1920s. The first national forest inventory was carried out by Yrjö Ilvessalo in 1923. Today the total area of forest land is 26 million ha, of which 20 million ha is productive forest land. The total growing stock is 1880 million $m^3$ and the total annual growth 79 million $m^3$. The growth has increased by almost 50% during the last 30 years. The average annual harvest has been about 55 million $m^3$ throughout the 1980s. One reason for the relatively high wood production of this northern country is the influence of the warm Gulf Stream waters off the coast of Norway.

The economically most valuable tree species in Finland are Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* [L.] Karst.), silver birch (*Betula pendula* Roth.) and downy birch (*Betula pubescens* Ehrh.).

Finns have always been dependent on the forests. The share of the forest industry in Finnish exports is now about 45%. Finland owns only 0.5% of the world's forest resources, but controls 5% of the total global forest industry production and 25% of the world's printing paper markets.

For many centuries, the main uses of Finnish forests were shifting cultivation and tar production. The lack of any silviculture meant that the forests were very unproductive at the beginning of this century. The early forest industry showed no improvement in silviculture. The main stand treatment was still heavy selective thinning from above, i.e., high-grading. In 1928, the first law for private forestry was made, prohibiting the devastation of forests and poor silviculture. Reforestation of clearcut areas has been compulsory since then.

During the last 25 years, stands have been treated using detailed guidelines. Options are given for the intensity and type of thinning, and recommendations are provided for other silvicultural measures. More than 50% of the wood for industrial use comes from clearcuts. The remainder comes from normal thinnings and seed-tree cuttings. The annual area being thinned averages about 250,000 ha, and this will increase in the near future.

## THE EFFECT OF THINNINGS ON STAND GROWTH

Many studies have shown that heavy thinnings decrease the total growth of a stand during the rotation. In a pine stand, growth loss has been 5 to 10%; the loss is a little bit less in a spruce stand. However, if we take natural mortality into consideration, the results are quite the opposite. A thinned stand produces about 20 to 25% more usable wood (DBH $\geq$ 10 cm) during the rotation.

In a thinned stand, trees attain large dimensions more quickly and there is intermediate income from thinnings. The results from a long-term experiment showed that income from a thinned stand, discounted to the beginning of the rotation over a 70-year period, was 80% greater than if the stand only been clearcut (Mielikäinen 1979).

Thinning intensity and timing have a profound, decisive effect on the value of developing stands. Heavy thinnings (low basal area remaining) result in a faster increase in tree dimensions while decreasing costs and keeping as little investment as possible bound in the stand.

What is the short-term effect of thinnings on wood production? The first thinning causes a growth loss of 5 to 25% during the initial 5-year period in a young Scots pine stand (Fig. 1). A Norway spruce stand, on the other hand, produces more or less the same amount of wood regardless of thinning intensity. Spruce, therefore, has the ability to concentrate volume production into fewer stems after thinning, especially in young and middle-aged stands, as a result of fast diameter increment. Figure 1 also suggests that the largest dominant trees also increase their diameter increment after heavy thinnings.

The long-term effects of thinnings on the growth and yield of a variety of species have been studied around the world. In Finland, many of the oldest thinning experiments were established in the early 1920s, soon after the founding of the Forest Research Institute. Some preliminary results from newer experiments are shown in Table 1.

Table 1. The effect of thinning intensity (residual stocking level) on the development of 40-year-old Norway spruce plantations in 20 years (age class 40–60 years, Site index $H_{100}$ = 30 m[a]).

| | Residual stocking level (% of basal area)[b] | | | |
|---|---|---|---|---|
| Growth | 100 | 90 | 75 | 60 |
| Volume (m$^3$/ha/yr) | 15.7 | 15.9 | 17.3 | 16.3 |
| Saw timber (m$^3$/ha/yr) | 14.5 | 13.2 | 16.6 | 15.9 |
| Height (cm/yr) | 46 | 46 | 46 | 50 |
| *At the end of the period:* | | | | |
| Stocking (stems/ha) | 1770 | 1220 | 730 | 420 |
| Mean diameter (cm) | 21.9 | 23.6 | 26.4 | 30.7 |

[a] $H_{100}$ = mean height of the 100 tallest trees at an age of 100 years.

[b] five replications, four thinning intensities; 100 = unthinned.

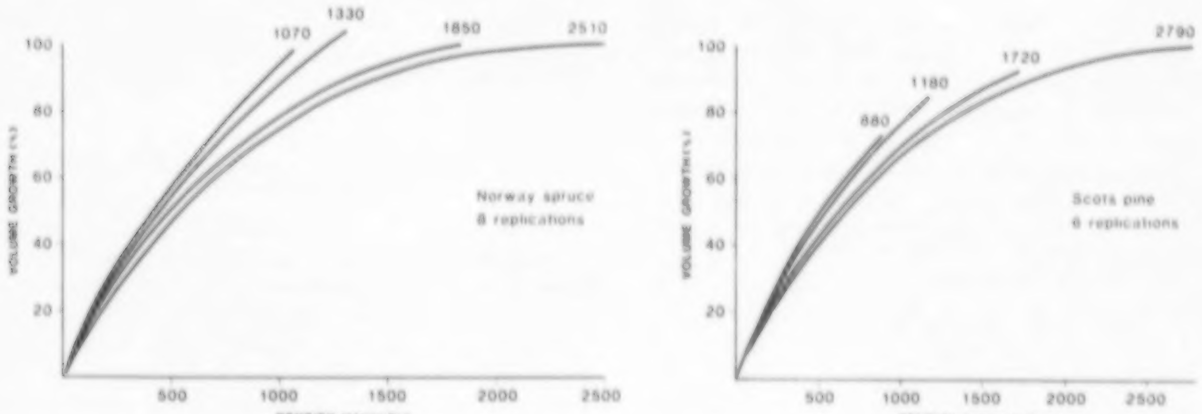


*Figure 1. The 5-year growth reaction of trees after different degrees of thinning at a dominant height of 12 to 13 m. From left to right, curves represent cumulative volume growth of trees in progressively smaller diameter classes (i.e., more trees per hectare).*

The results in Table 1 are from a long-term experiment with four thinning intensities and five replications. Thinning intensity is expressed as a percentage of the basal area for unthinned plots. The experimental plots have been measured and thinned five times during the past 20 years.

From Table 1, we can see that stemwood and sawtimber production of Norway spruce on good sites are roughly constant, regardless of the stocking level. On less fertile soils, heavy thinnings decrease the rate of growth, especially in old stands. A heavy thinning results in faster diameter increment, a shorter rotation and superior economy. The effect of revenues from early thinnings and the low stocking levels will be further emphasized when interest on the investment is calculated.

In Finnish forestry practice, the most common thinning method is thinning from below, in which mainly the smallest, slowest-growing trees are removed. The latest studies show that in an even-aged and well treated stand, a thinning from above does not decrease wood production if the intent of the thinning is similar to that for thinnings from below (Vuokila 1977, Hynynen and Kukkola 1989, Eriksson 1990). Thinning from above is especially essential in young Scots pine stands that have problems with technical quality (e.g., excessively large branches). Furthermore, it is reasonable to remove some of the largest trees in old stands to avoid producing excessively large trees.

## STAND TREATMENT IN PRACTICE

### Growing sapling stands

In Finnish forestry practice, planting density is 2000 to 2500 seedlings/ha. With natural regeneration, the density can sometimes be higher. A young stand will be treated for the first time when the height of the dominant trees is 1 to 2 m. Competing hardwood saplings are removed. Norway spruce stands are thinned to a density of 2000 stems/ha. For quality purposes, the thinning of the young stand is carried out at a stand height of 4 to 6 m in Scots pine stands.

Treatment of young stands *must not* be overlooked. The objective of this treatment is to leave uncut trees that will reach merchantable dimensions before the first commercial thinning at a height of 12 to 14 m. In Finland, a tree with a DBH of 10 to 11 cm has a positive merchantable stumpage value; i.e., a value higher than the cost of timber harvesting and long-distance transport from elsewhere.

### Thinning models

Forest stands in Finland are, as a rule, even-aged. Uneven-aged forest management can be accomplished with our tree species only under very limited circumstances, and not for a full normal rotation. Our harvesting methods are also not very suitable for uneven-aged stands.

An example of a thinning model used in Finland is shown in Figure 2. In such models, the first commercial thinning will usually come when the stand height reaches 12 to 14 m. In such a thinning, the number of stems is reduced to 1000 to 1400 stems/ha, depending on tree species and soil fertility. In birch stands, however, the residual stem number is only 700 to 800 stems/ha. The removal of merchantable wood amounts to about 40 $m^3$/ha, and trees have an average volume of about 50 to 60 $dm^3$ (11 to 13 cm DBH).

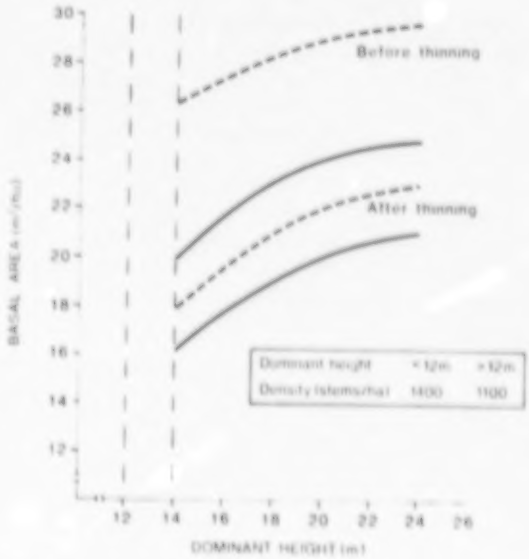
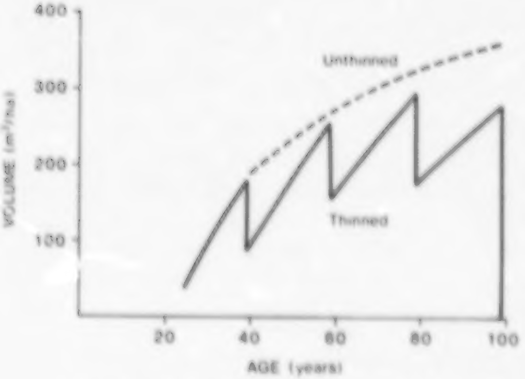


*Figure 2. An example of a thinning model used in the private forests of southern Finland.*

The timing and intensity of subsequent thinnings will be determined from a combination of stand height and basal area. A thinning would be recommended when the basal area reaches the upper limit described by the thinning model. By using thinning models, anywhere from two to five thinnings can occur during the rotation. At each thinning, 50 to 80 $m^3$/ha are removed, resulting in significant income to the forest owner. The harvest price will be negotiated based on the amount of wood, its dimensions, and the transportation distance.

Previously, trees were marked for removal. Today, the selection of trees to be removed is made by knowledgeable machine operators or forest workers. To determine the proper thinning intensity, the machine operator needs a thinning model that can be used directly from the cab. The stem number can readily be determined in the semicircle that the sweep of the machine's boom transcribes. The thinning model suited for a forest worker is also based on tree diameter and stem number.

Estimation of the long-term profitability from thinnings requires the calculation of stand yield, revenues and costs over the whole rotation period. A stand simulator called MELA (Siitonen 1983) is available for this purpose. Originally, MELA was developed for long-term prediction and optimization of forest management on large areas. It also allows comparison of the effects of different thinnings on the total yield of a stand during the rotation. An example of a sequence of thinnings produced by MELA is shown in Figure 3. The impact of intermediate thinnings can clearly be seen.



Stand characteristics at the end of the rotation

| | Unthinned | Thinned |
|---|---|---|
| Stem number | 1360 | 820 |
| Standing volume (m³/ha) | 365 | 278 |
| Mean diameter (cm) | 19 | 22 |
| Thinned volume (m³/ha) | - | 303 |

*Figure 3. An example of the simulated development of a Scots pine stand, with and without thinnings. (Site index $H_{100}$ = 24 m).*

The effect of thinnings on total yield and on the economy of Finland as a whole is currently being studied in a project that will end in 1991.

## TIMBER HARVESTING IN THINNED STANDS

### Methods and machines

Finland's total commercial timber harvest in 1989 was about 50 million m³, of which more than 10 million m³ came from thinnings. This represented an area of 250,000 ha. In the near future, the area on which first commercial thinnings will be conducted will increase. The mean stem volume in current first commercial thinnings ranges from 51 to 57 dm³ and from 112 to 120 dm³ in later thinnings (Lilleberg and Raitanen 1989). In thinnings and clearcuts, almost all harvesting utilizes the shortwood method, with either manual or mechanized means to fell, delimb and buck timber to the most desirable quality and size, and load-carrying forwarders for transporting wood from the stump to the roadside. This technique is used because of the small size of the stems and the desire to minimize damage to the residual growing stock. The methods are also well suited for clearcutting under Finnish conditions.

Table 2 shows that the first thinnings are more than twice as expensive as the final cut on a per-cubic-metre basis. It can be seen that the most expensive working phase is cutting. Off-road transport, on the other hand, has quite similar costs regardless of the harvesting phase, but can cost slightly less as the stand matures.

Table 2. Harvesting costs during the rotation. Manual felling and off-road transport with forwarder were used (data from Hakkila 1990).

| | Harvest costs (FIM/m³) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Scots pine | | | | Norway spruce | | | |
| | Thinning[a] | | | Final | Thinning[a] | | | Final |
| | I | II | III | cut | I | II | III | cut |
| Planning | 12 | 8 | 6 | 3 | 12 | 9 | 6 | 3 |
| Administration | 3 | 2 | 2 | 1 | 4 | 2 | 2 | 1 |
| Cutting | 59 | 33 | 25 | 20 | 75 | 42 | 32 | 26 |
| Off-road transport | 24 | 24 | 22 | 19 | 25 | 24 | 22 | 19 |
| Total | 99 | 67 | 55 | 44 | 116 | 76 | 62 | 50 |

[a] Stem size (m³): 1st thinning = 0.05, 2nd thinning = 0.10, 3rd thinning = 0.20, final cut = 0.30

Currently, mechanized harvesting accounts for about 70% of the total area in clearcutting and 15% of that in thinning. By the mid 1990s, it is estimated that almost 80% of all wood harvested will be processed without the use of manual labor. Improvements in the efficiency of manual and mechanized methods and the shortage of forest workers have encouraged mechanization in the forest.

To compare the cost structures of different harvesting methods, a computer program has been prepared. The results of computer analyses show that manual work is still cheaper than fully mechanized systems for the first thinnings. On the other hand, mechanization is the cheapest way to harvest wood during later thinnings (mean stem volume >150 dm$^3$) and clearcutting.

In a fully mechanized thinning, felling and processing make use of single-grip harvesters (Fig. 4). The weight of a normal single-grip harvester is about 10 tonnes, and it has a reach of 10 m. The strip-road width requirement is 4 m and the optimum distance between roads is 20 m. Small harvesters are also used in first thinnings. These machines need strip roads that are 3 m wide and spaced at 15-m intervals. The working methods of a single-grip and a small-sized harvester are shown in Figure 5.

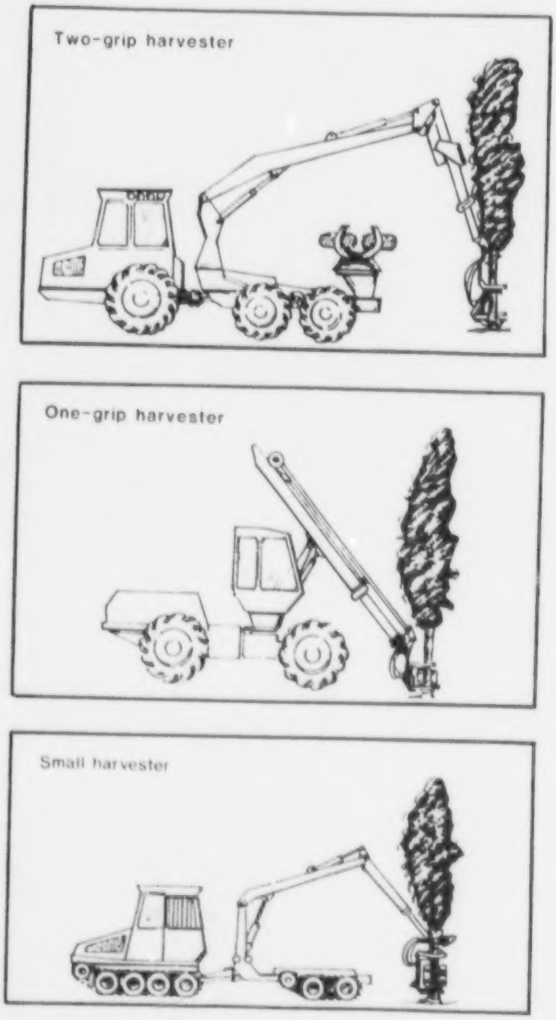


*Figure 4. Some machines suitable for use in thinnings.*

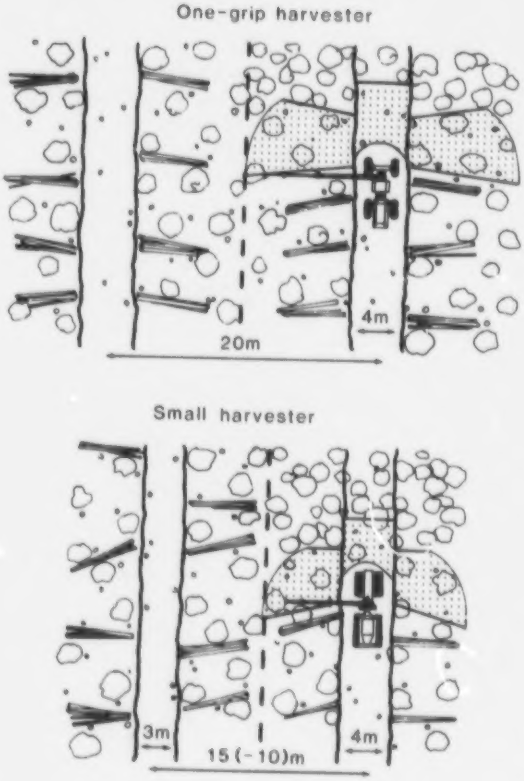


*Figure 5. The working method of harvesters used in thinnings.*

Double-grip harvesters are not used in thinning, and are more suitable for clearcutting. The double-grip allows the operator to hold several trees before bunching. As such, double-grip harvesters are heavier than single-grip harvesters. Wood transport uses a 10-tonne forwarder, with strip roads every 20 or 30 m.

## Effect of timber harvesting on growth and yield

Thinning creates an immediate growth loss when evaluated on a stand basis. Strip roads cover about 15 to 20% of the stand area. The positive growth reaction of trees nearest to strip roads will diminish the loss to about 1% of the total yield over the course of the rotation (Bucht 1977, Isomäki and Niemistö 1990). Much more serious is the risk of damage to residual stems and roots when using machines for thinning; this damage can cause both growth and quality losses. The negative effect of machine rutting on the growth of the trees nearest to the striproad can be as serious as a 25% growth reduction, which is equivalent to the positive effect produced by the road.

Root damage within 0.7 m of the stem and stem wounds act as infection courts for fungi in the development of rot in Norway spruce and birch. The resulting change in a stem reduces it from sawlog quality and dimensions to something suitable only for pulpwood, an economic loss that exceeds all growth losses. Avoiding damage is much more important than counting the width of strip roads or the thinning methods themselves.

The first evaluations of the effects of damage caused by processors and harvesters in the early 1980s were alarming. As a rule, more than 10% of the residual trees had some damage after thinning. With improvements to forest machines and education of machine operators, the amount of damage has been decreased to a tolerable level. Currently, damage caused while thinning in stands occurs on less than 5% of the remaining trees after a fully mechanized felling and processing operation (Mäkelä 1989, Siren 1989). The corresponding damage attributed to off-road forwarding is about 1%. The skill of the machine operator is the most important factor in avoiding damage.

## WHY DO WE THIN IN FINLAND?

Thinnings have always had an important role in supplying the needs of the forest industry in Finland. A lack of raw material previously compelled us to thin. After decades of intensive silviculture, the total growth of Finnish forests has increased by more than 40% and it now exceeds the total annual harvest by 25 million m$^3$.

The primary reason that stand thinning is practiced by forest landowners is the realization of an economic return. By harvesting the normal natural mortality, by obtaining early revenues, and by having faster diameter development, a regularly thinned and regenerated stand can be very profitable.

The prerequisites for making thinning economically feasible are (1) intensive thinning of sapling stands, (2) using the most appropriate harvesting machines and technology, and (3) sufficient industrial use of small-diameter wood. On Finland's relatively easy terrain, the shortwood method has been shown to be suitable for both thinning and clearcutting.

## LITERATURE CITED

Bucht, S. 1977. Vad kostar stickvägarna i tillväxt? Summary: The influence of strip roads on increment at the first thinning in Scots pine forests. Skogen 6:218–222.

Eriksson, H. 1990. Hur har de gått med höggallringen? Sver. Skogs. Tidsk. 2:42–57.

Hakkila, P. 1990. Harvennusmetsien puunkorjuu. Me elämme metsästä — metsä elää meistä. Isäntäakatemia. Kurikka 1990. Yliopistopaino (Univ. Helsinki Press), Helsinki. p. 49–58.

Hynynen, J. and Kukkola, M. 1989. Harvennustavan ja lannoituksen vaikutus männikön ja kuusikon kasvuun. Summary: Effect of thinning method and nitrogen fertilization on the growth of Scots pine and Norway spruce stands. Folia For. 731. 20 p.

Isomäki, A. and Niemistö, P. 1990. Ajourien vaikutus punston kasvum Etelä-Suomen nuorissa kuusikoissa. (The effect of strip roads on the growth and yield of young spruce stands in Southern Finland.) Folia For. 756. 36 p.

Lilleberg, R. and Raitanen, A. 1989. Etelä-Suomen harvennusmetsien määrä ja korjuuolosuhteet vuosina 1988–2000. Summary: The amount of thinning forests in Southern Finland — harvesting conditions 1988–2000. Metsätehon tiedotus 401. 19 p.

Mäkelä, M. 1989. Koneellinen puunkorjuu kuusikon ensimmäisessä harvennuksessa. Mechanical harvesting in first thinning of spruce stands. Metsäteho Review 10/1989. 6 p.

Mielikäinen, K. 1979. Alaharvennusten vaikutus männikön tuotokseen ja arvoon. Abstract: The influence of low thinnings on the wood production and value of a pine stand. Folia For. 401. 23 p.

Siitonen, M. 1983. A long term forestry planning system based on data from the Finnish National Forest Inventory. Forest Inventory for Improved Management. Proc. IUFRO Subject Group 4.02 meeting in Finland, 5–9 September 1983. Univ. Helsinki, Dep. For. Mensuration and Manage. 17:195–207.

Siren, M. 1989. Pienet hakkuukoneet varhaisissa harvennushakkuissa. Summary: Small multi-function machines in early thinning operations. Folia For. 743: 1–29.

Vuokila, Y. 1977. Harsintaharvennus puuntuotantoon vaikuttavana tekijänä. Abstract: Selective thinning from above as a factor of growth and yield. Folia For. 298. 17 p.

# ASSESSING THE ECONOMIC IMPACTS OF THINNING IN NORTHERN ONTARIO

*(A paper of the presentation was not submitted by the author.)*

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## ABSTRACT

The potential economic benefits of precommercial and commercial thinning are discussed. A simple example, based on a subjective assessment of the effects of precommercial thinning of jack pine (*Pinus banksiana* Lamb.) in northern Ontario, is used as a starting point for a discussion of the importance of the quantifiable outputs and economic benefits of thinning. Analytical techniques for optimizing wood supply are suggested as a way of determining prices for the economic evaluation of thinning alternatives.

## RÉSUMÉ

La discussion porte sur les avantages économiques potentiels de la coupe d'éclaircie précommerciale et commerciale. Un simple exemple, fondé sur l'évaluation subjective des effets de la coupe d'éclaircie précommerciale dans un peuplement de pins gris (*Pinus banksiana* Lamb.), dans le nord de l'Ontario, sert de point de départ à la discussion sur l'importance des résultats quantifiables et des avantages économiques de la coupe d'éclaircie. Des techniques d'analyse d'optimisation des réserves de bois sont proposées comme façons de déterminer le coût de l'évaluation économique des solutions de rechange à la coupe d'éclaircie.

# STAND TENDING — ARE WE DOING ENOUGH?

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## ABSTRACT

The environmental/preservationist movement is relentlessly reducing the number of prime forests available for future harvesting by the forest industry. Vastly increased stand-management programs must be implemented immediately if annual allowable cuts for sawlog timber are not to be drastically reduced as a result.

## RÉSUMÉ

Le mouvement des protecteurs de l'environnement entraine implacablement une diminution du nombre de forêts de choix qui pourront être exploitées par l'industrie forestière à l'avenir. Il faut immédiatement mettre en œuvre des programmes d'aménagement des peuplements beaucoup plus importants pour éviter qu'on réduise de façon draconienne les coupes annuelles permises en vue de l'obtention de grumes de sciage.

## ARE WE DOING ENOUGH?

To set the stage for the closing presentation of the conference, some "forestry truths" must be emphasized. Some of the less desirable facts about forestry in Canada are:

- Twenty-two million hectares of forest land harvested in the past remains unrestocked with anything remotely resembling merchantable timber.
- In most provinces, current harvesting is creating more unstocked areas each year; B.C. is currently the only province that is reforesting all logged areas.
- Forests on the shrinking forest land base are being harvested faster than they are growing.
- The overall health of our forests is declining as a result of global warming and/or pollution pressures.
- Wildfires are burning increasingly vast areas of forests in unusual dry periods that are recurring with greater frequency.
- Shortages of sawlog timber are occurring almost everywhere in Canada.
- Closer to the venue of this conference, and more meaningful to the current deliberations, Ontario has been adding to its unrestocked forest area annually by restricting the reforestation budget for current logging. For the past 4 years, it has planted only 30% of the area logged. As well, Ontario presently has somewhere between 4 and 6 million ha of not sufficiently restocked (NSR) forest land, and this is increasing every year. The Ontario Ministry of Natural Resources (OMNR) has recorded more than 2 million ha of NSR just on private land in southern Ontario — in prime growing areas.

On a more positive note, ENVIROFOR, a conference hosted by the Canadian Forestry Association in May 1990, yielded some positive thoughts. This conference was billed as "The first time in Canadian history when senior environmentalists and forest industry executives will meet to discuss the future of Canadian forests. The time for confrontation is over. The time for cooperation is *now.*" The overall conclusion of this conference was that "Forest preservation is here to stay and will be increasing in momentum."

The worldwide environmental/preservationist movement is relentlessly — and successfully — pursuing its goal of reducing the area of prime forests available for future harvesting by the forest industry. In Canada, the political pressures created by this movement will rapidly increase in the immediate future, and the available merchantable forest land base will be reduced substantially. South Moresby Island, the Carmanah Valley, the Stein Valley and the Temagami wilderness are now familiar names to most Canadians. Indications are that shortly there will be dozens of areas in every province that are similarly targeted for forest preservation and that will become just as well known.

To make up for these forest inventory depletions, vastly increased stand-management programs will have to be implemented immediately in "forestry safe havens" if the supply of timber — especially sawlog timber — available for industrial purposes is not to be drastically reduced as a result. Failure to implement this recommendation will result in economic and social chaos in much of rural Canada, where current industrial forest activity is the mainstay of many communities.

If you think this is fearmongering, perhaps a brief look at what is currently happening in the prime timber-growing areas of the northwestern United States will scare you from your complacency. Prices of sawlog timber from Oregon's National Forest, which contains the U.S. National Forest System's largest volume of merchantable timber, averaged an estimated $350 per thousand board feet (Scribner Scale) last year. This is 75% higher than the average of $200 for the decade. Much of this price increase can be attributed directly to the impending scarcity of supply generated by "Spotted Owl set asides", or SOHA's as they are called.

Pressured by an active, well organized preservationist movement that wants to save the remaining "old growth" forest habitat of the Spotted Owl, the U.S. Fish and Wildlife Service declared the owl an endangered species in June of this year. The USDA Forest Service has subsequently made a recommendation aimed at protecting the owl that would take more than 1.2 million ha of previously unprotected forests out of commercial production. This recommendation — if implemented — may soon cut harvesting on federal land in the U.S. Northwest by nearly one-third, and could result in the loss of nearly 30,000 jobs by the year 2000. Forest industry analysts say that this, combined with a new Forest Service national forest plan and other proposed cuts, will decrease the timber harvest in the U.S. Northwest to 4.33 billion board feet in 1990, from more than 7.0 billion board feet in 1989, a reduction equivalent to approximately 10% of the total annual American timber production.

In Canada, even without the pressure created by forest inventory depletions, there are signs almost everywhere that the lack of suitable sawlog timber is becoming a crisis situation. When Weyerhaeuser Canada Ltd. announced in February 1990 that it was closing its Princeton, B.C., mill because of a sawlog shortage, company spokesman Bob Taylor attributed the decision to the fact that the region's five sawmills had bigger appetites for wood than local supply could meet. Ian Howe, operations manager with the Ministry of Forests in Merritt, B.C., said that the problem was not unique to that area. "Every timber supply area in the province has an over-capacity in its mills versus what the annual allowable cut is."

In Ontario, the total area harvested annually has increased by almost 10% between 1984 and 1988 (Table 1). Several chief foresters of major lumber companies have stated that their operations are faced with both immediate and long-term shortages of sawlogs, and that many other companies in Ontario were facing imminent shortages. Operational logging plans for some companies show projections that as much as 30 to 40% of their annual allowable cut will be deleted as a result of impending environmental guidelines and future forest-preserve set-asides.

Recent Ontario stand-tending statistics (Table 2) for Crown lands indicate an appalling lack of commitment to management of quality second-growth forests in the province.

Table 1. Area of forest harvested on Crown and Forest Management Agreement land in Ontario from 1984 to 1988 (years ending 31 March).

| | Area harvested (ha) | | | | |
|---|---|---|---|---|---|
| Type of cut | 1984 | 1985 | 1986 | 1987 | 1988 |
| Even-aged | 187,319 | 185,172 | 192,268 | 196,374 | 205,146 |
| Uneven-aged | 30,487 | 32,812 | 31,249 | 32,090 | 32,042 |
| Total | 217,806 | 217,984 | 223,517 | 228,464 | 237,188 |

Table 2. Annual stand-tending activities on Crown lands in Ontario for the 1985 to 1989 fiscal years.

| Silvicultural | Area (ha) of stands tended | | | | |
|---|---|---|---|---|---|
| operations | 1985 | 1986 | 1987 | 1988 | 1989 |
| Hand cleaning | 7,696 | 9,384 | 10,660 | 5,250 | 2,031 |
| Herbicide spraying | 42,023 | 57,566 | 59,279 | 64,071 | 71,627 |
| Thinning and improvement | 6,591 | 8,845 | 9,404 | 7,191 | 4,722 |
| Pruning | 596 | 934 | 1,017 | 459 | 247 |
| Fertilization/drainage | 58 | 65 | 9 | 9 | – |
| Total | 56,964 | 76,794 | 80,369 | 76,980 | 78,627 |

Quebec's sawlog supply from public forests has been reduced from a high of 16 million $m^3$ in 1974 to somewhat less than 8 million $m^3$ in 1987 (Fig. 1). The provincial government is desperately trying to encourage more deliveries from private woodlot owners, who are becoming increasingly dissatisfied with the prices they have been receiving for their timber. Furthermore, Quebec and some Maritime provinces have been importing sawlogs for decades to feed their mills along the U.S. border. Political pressures in the U.S. to keep the logs — and the jobs — in these northern supplier states will soon force the closure of many mills in eastern Canada.

## STAND TENDING IN CANADA

Canada will be moving rapidly toward harvesting of second-growth forests in the years ahead. Hence, a comparison of our stand tending activities with those of Sweden — where harvesting of second- and third-growth stands is the norm — may be instructive. Sweden, a country that would fit several times over into British Columbia, currently produces 55 million $m^3$ annually from a forest land base of 23 million ha. The current growth rate equals 2.9 $m^3$/ha/yr, versus approximately 1 $m^3$/ha/yr in Canada. Sweden is currently mechanically spacing 270,000 ha per year, and has been operating near that level for several years now. Recent figures (1983 to 1986) for *all of Canada* show an average of 170,000 ha for all methods of stand tending — including the use of herbicides (Fig. 2).

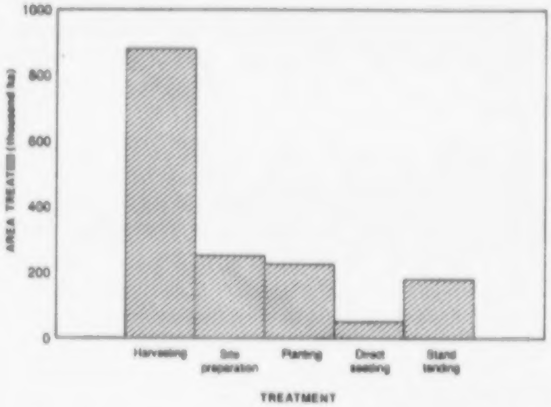

*Figure 2. The average area of various silvicultural activities carried out in Canada from 1983/1984 to 1985/1986.*

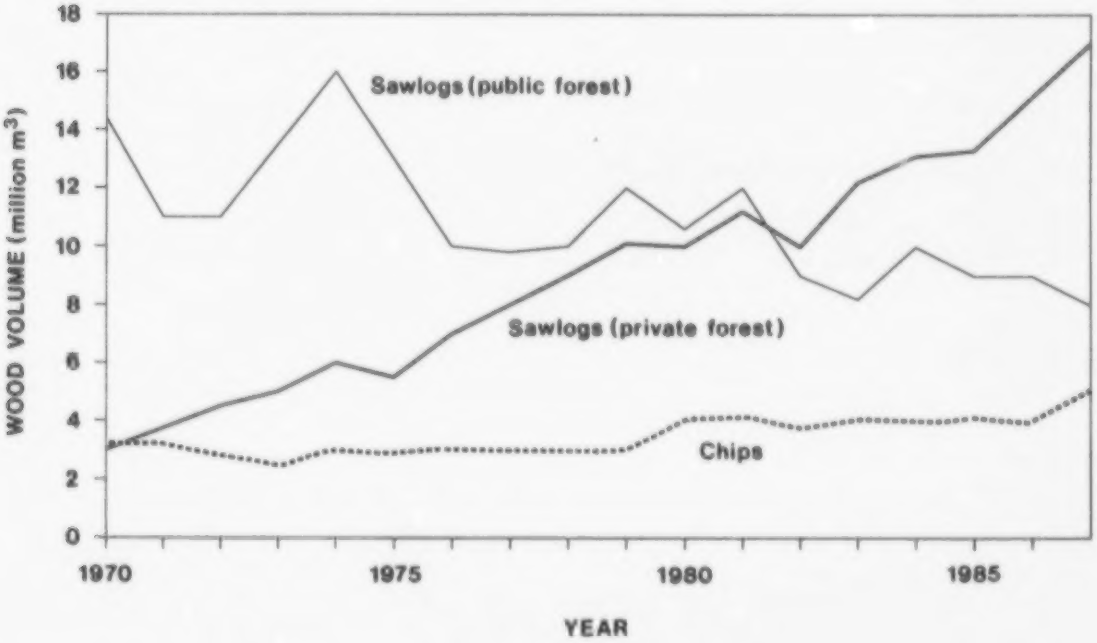

*Figure 1. Quebec's wood supply from 1970 to 1987.*

With the advent of Forest Resource Development Agreements (FRDAs), a considerable infusion of funds for stand tending occurred. Table 3 shows the effect of this funding on stand-tending activities. It also shows how the province of Nova Scotia capitalized on this funding, accomplishing about 25% of all tending done across Canada to the end of 1986–1987.

Table 4 shows the expectations associated with the foregoing activities. The average cost of stand tending for the year was $289.08/ha, and ranged from $171.24 to $562.14.

## ACTION PLAN REQUIRED!

To determine whether the patterns of stand growth in Canada and the current levels of intensive silviculture will support our expectations and requirements for future timber supply in Canada, the following questions must be addressed:

- What is the current status of the nation's pulpwood and sawlog timber resource?
- How many of the 350 forest-industry-dependent communities are facing immediate and long-term shortages of pulp or sawlog timber?
- What level of intensive silvicultural forest management is required for us to maintain our position in the world softwood export market?
- Who is responsible for doing this work?
- How much will it cost?

Table 3. Area of all stand tending performed under forest economic and regional development agreements.

| | Area of stand tending (ha) | | | | | |
|---|---|---|---|---|---|---|
| Province | 1982–1983 | 1983–1984 | 1984–1985 | 1985–1986 | 1986–1987 | Total |
| British Columbia | 0 | 0 | 0 | 5,546 | 34,587 | 40,133 |
| Alberta | 0 | 0 | 0 | 30 | 55 | 85 |
| Saskatchewan | 0 | 0 | 56 | 764 | 629 | 1,449 |
| Manitoba | 0 | 0 | 618 | 339 | 642 | 1,599 |
| Ontario | 0 | 0 | 8,806 | 10,605 | 28,751 | 48,162 |
| Quebec[a] | 0 | 0 | 0 | 14,561 | 16,119 | 30,680 |
| New Brunswick | 0 | 0 | 5,378 | 24,183 | 8,758 | 38,319 |
| Nova Scotia | 4,454 | 6,300 | 11,580 | 16,762 | 17,299 | 56,395 |
| P.E.I. | 0 | 473 | 1,037 | 1,160 | 1,217 | 3,887 |
| Newfoundland | 0 | 0 | 0 | 0 | 6,788 | 6,788 |
| Canada | 4,454 | 6,773 | 27,475 | 73,950 | 114,845 | 227,497 |

[a] Forest Development Subsidiary Agreement and the Gaspé and Lower St. Lawrence Program

Table 4. Expenditures for all stand tending[a] performed under forest economic and regional development agreements.

| | Expenditure (thousand $) | | | | |
|---|---|---|---|---|---|
| Province | 1982–1983 | 1983–1984 | 1984–1985 | 1985–1986 | 1986–1987 |
| British Columbia | 0.0 | 0.0 | 0.0 | 2,151.0 | 7,438.6 |
| Alberta | 0.0 | 0.0 | 0.0 | 53.8 | 22.5 |
| Saskatchewan | 0.0 | 0.0 | 11.1 | 239.7 | 239.6 |
| Manitoba | 0.0 | 0.0 | 586.8 | 147.5 | 290.0 |
| Ontario | 0.0 | 0.0 | 1,172.5 | 1,966.0 | 4,923.2 |
| Quebec[b] | 0.0 | 0.0 | 0.0 | 6,571.2 | 6,107.8 |
| New Brunswick | 0.0 | 0.0 | 2,953.8 | 5,210.2 | 4,923.2 |
| Nova Scotia | 742.4 | 1,673.3 | 2,259.7 | 4,110.0 | 5,004.7 |
| P.E.I. | 0.0 | 248.0 | 474.4 | 601.9 | 609.7 |
| Newfoundland | 0.0 | 0.0 | 0.0 | 0.0 | 3,638.7 |
| Canada | 742.4 | 1,921.3 | 7,458.3 | 21,051.3 | 33,198.9 |

[a] Figures may not be identical to those quoted in other reports because of differences in the sources of data and methods of compilation.

[b] Forest Development Subsidiary Agreement and the Gaspé and Lower St. Lawrence Program

The following are some facts to exemplify the situation on the west coast of Canada. British Columbia must reduce its timber harvest to conform with an annual allowable cut (AAC) based on sustained-yield principles and, over time, the allowable cut itself will have to be reduced further unless the province is willing to manage its forests more intensively (Les Reed, Professor of Forest Policy, University of British Columbia, personal communication). Reed noted that the AAC for the province is about 77 million m$^3$, but that from 1987 to 1989 the harvests have ranged from 86 to 90 million m$^3$. Add to this the very real possibility that, as environmental/preservationist pressure in the province increases, hundreds of thousands of hectares presently listed as commercial forest will not be available for harvest, and one is faced with a crisis of immense proportions in that province. Given the lack of available wood supplies in many areas of B.C., sawmills can only operate at 60 to 65% of their capability.

The federal government realizes the predicament that Canada's forests are in. Prime Minister Brian Mulroney told delegates to the Canadian Pulp and Paper Association's annual convention in February 1990 that his government was preparing a new environmental policy based on sustainable development. He also told the delegates that his government would renew its $1.1 billion reforestation program — despite the present tight fiscal situation[1]. However, the new federal forestry ministry has had its overall budget in 1990 reduced from $235 million to $207 million.

I stress again, failure to implement this recommendation for vastly increased, intensive stand-management programs, will result in severe economic hardship and social chaos in much of rural Canada, where current industrial forest activity is the mainstay of many communities, and urban Canada will not escape the consequences.

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[1] The Financial Post, 5 Feb. 1990.

# SESSION VI
# Reports, Recommendations and Closing Remarks

# SUMMARY OF SESSION I: WHAT IS BEING DONE OUTSIDE ONTARIO?

*K.M. Brown*
*Professor*
*School of Forestry, Lakehead University*
*Thunder Bay, Ontario*

The first session was entitled "What is being done outside of Ontario?". We heard from four speakers; two were our international neighbors from Sweden and the United States, and the other two were our Canadian neighbors from British Columbia and New Brunswick.

The first speaker was Linus Anderson from the Swedish University of Agricultural Sciences, Umeå, Sweden, who spoke about the effects of initial spacing and thinning on Norway spruce and Scots pine in Sweden. His results confirm the general growth and yield trends that we have come to expect from tending operations. He also showed how response differs from one species to the next and he suggested that, perhaps, the shade-tolerant species respond differently than the shade-intolerant species. In addition, he emphasized the importance of recent advances in the mechanization of thinning operations in making these operations generally successful and economical.

The second speaker was Gary Lloyd from the British Columbia Ministry of Forestry. His talk was packed with information about what seems to be a very active spacing and thinning program in British Columbia.

Gary left us with two important thoughts. First, he said that if we don't thin, we suffer two expensive consequences: (1) the sizes of the products that are available at harvest are reduced, and (2) the productivity of our forestry operations is diminished. Second, he said that Canadian forest managers *need* managed-stand yield tables. This same point was reiterated by other speakers in subsequent presentations.

Our third speaker was Joakim Hermelin from the Policy Secretariat, Province of New Brunswick. Joakim told us about the historical trends in tending operations in New Brunswick. He emphasized the need to train and motivate silvicultural workers. As well, he pointed out that there are supervisors and even managers who must be oriented to these kinds of operations.

The final speaker in this session was Bill Botti, of the Michigan Department of Natural Resources (Lansing, Michigan). Bill gave us an often humorous historical account of forest management in Michigan over the last 25 years. He certainly got our attention when he told us his department borrowed $5 million from a bank to finance forestry operations. Then, he really amazed us when he read his epic poem dedicated to "Space to Grow".

I was able to detect three broad themes from these four presentations. One theme was that there is a widespread shift from regeneration to tending. That doesn't mean that people are not interested in regeneration anymore, but rather that the relative emphasis seems to be shifting from a preoccupation with regeneration to a more balanced treatment of regeneration and tending operations. At the same time, there seems to be a shift from extensive to intensive silviculture. The second point is that training really is important. If Ontario isn't moving in this direction, then a training program should be considered. The third thing is that managers or silvicultural decision-makers, whoever these people are, need to have cost/benefit information in order to do their job. The benefit side of that equation requires growth and yield information in a form that allows managers to anticipate the response of stands to management.

Finally, I recommend that a place be found in the proceedings for Bill Botti's poem.

# SUMMARY OF SESSION II: SPACING AND THINNING IN ONTARIO

*J.B. Atherton*
*Manager, Special Projects*
*E.B. Eddy Forest Products Ltd.*
*Espanola, Ontario*

I would first of all like to thank the speakers Mike Waldram and Rob White, Paul Hosick and Ron Calvert, Martin Litchfield, Jim Miller and Naomi Donat, Glen Swant, and Brian Nicks for their time and effort in preparing and delivering their papers. I would also like to thank Rob Galloway for keeping it all together and on time.

The purpose of Session II was to give an overview of thinning in Ontario. My job is to comment on what was presented. I do not intend to parrot back all the statistics—no one could write that fast!

The climate and soils of Northwestern Ontario are favorable for natural regeneration and seeding. Combined with a high incidence of wildfire, there are many hectares needing treatment. Unfortunately, very little is being done due to a lack of funds. The high incidence of fire makes investment in thinning a risky business.

It is predicted that the area available for thinning in North Central Region will increase by 250%, to 5000 ha, in the next 5 years. In Northern Region, natural regeneration (with jack pine) and seeding are not the prescription of choice due to conditions in the region. But as funds tighten up, seeding and subsequent tending will be used more often. In Northeastern Region, sawlogs are the product of choice and spacing has some potential.

All Regions agree that thinning provides:

- a reduction in rotation age
- possibilities for reducing regeneration cost through seeding and subsequent thinning, and
- possibilities for increasing the volume per tree.

From the industry's point of view, we received some insight into thinning as part of a regeneration strategy.

1) The trees we are going to harvest 75 years from now are presently growing. What are we going to do with these trees?

We are looking at a wood shortage 20 to 30 years away. The age-class distribution is basically the same throughout Ontario — we have a shortage in the 20-40 year age class and an excess in the overmature age classes. We have to start growing wood to fill that hole; planting more trees won't do it, but storing wood on the stump, reducing rotations and commercial thinning will. Glen Swant indicated that introducing commercial thinning into the equation rendered the program uneconomic. However, flail delimbing/debarking and chipping in the bush are practices that are coming into their own and could have a place in reducing the handling cost for wood.

2) We have to determine what products to produce. We heard from two sawlog-oriented companies and their interest is in increasing tree size. A pulp company might look at things differently—they might prefer to target maximum fiber per hectare, especially if they were working toward debarking and chipping in the bush.

3) From a harvesting point of view, concentrating volume on a few stems would be a logical strategy. Harvesting systems of the future will require mechanisation to offset a shortage of labor. We will not be able to attract people to cut trees with power saws. (We should consider this labor problem in developing thinning systems.)

4) Robotics will no doubt have a place in our future harvesting programs. Evenly spaced trees will be an important part of that strategy.

5) We face constraints in all areas: a cap on seedling production, restrictions on the areas available for timber production, funding, an oversupply of softwood pulpwood, and limits on the use of herbicides. Seeding and tending may have a place in alleviating some of these constraints.

6) We need:

- funding — you saw the effect of COFRDA funding in Brian Nicks' presenation. It's not great having an agreed-upon rate of payment for thinning but no money,
- growth and yield data to permit prediction capability, and
- a production policy to determine how much is enough. Most Forest Management Agreements have one for their areas. A provincial strategy is

necessary and this is now incorporated into the Peter Pearce study commissioned for the Ontario Ministry of Natural Resources.

7) We have to:

- experiment with spacing of planting stock vs seeding and thinning;
- determine the effect of various spacing regimes on wood quality, height and diameter growth (my gut feeling is that it should happen, but at what rate?);
- ROI (Return On Investment) ranks up there with increasing the MAD (Mean Annual Depletion).

We are competing for land with other users and we have to make the best use of the sites we have. Every circumstance will require its own plan—let's get at it! Keep an eye on the noise coming out of Europe about a boycott of products from unmanaged forests... remember what happened to the seal hunters in Newfoundland.

# SUMMARY OF SESSION III:
# BIOLOGICAL CONSIDERATIONS

*P.A. Addison*
*Directer, Forest Resources and Environment*
*Forestry Canada, Ontario Region*
*Sault Ste. Marie, Ontario*

## INTRODUCTION

A year or so ago, when I was at the Society of American Foresters Annual Meeting, a speaker quipped that doctors bury their mistakes but a forester has to live with his for a full rotation. In listening to the various talks that we have heard during the last two days, it strikes me that this is no longer true. We have the ability to manipulate stands in a way that may very well compensate for past mistakes or for some of nature's disturbances that we cannot control.

Fundamental to the whole issue of stand manipulation is stewardship and the importance of strategic thinking, as Les Reed indicated. Although we do have a great deal of information available to us, in many cases it is neither synthesized into a useful form nor is it included in current practices. We are starting to feel the need to use this information more today than ever before. We have finally realized that "seat-of-the-pants" forestry is just not good enough and our environmental-activist friends have made it crystal clear that they will settle for nothing less than the best we can do in forest management. In the case of silviculture, good practices are equivalent to good environmental protection.

## KEY POINTS OF THE SPEAKERS

### David DeYoe

Dave gave us quite a comprehensive "tree's-eye-view" of a tree's fight for survival. Environmental factors such as water, light and nutrients are often in short supply and, basically, "it's a jungle out there". Dave also reminded us of the myriad of biotic factors including the nippers, clippers and strippers that also contribute to the stress that a tree is under. Most importantly, he pointed out that we need to understand the functioning of both tree and ecosystem in order to determine the best way of intervening to make the system produce what we want.

### Harald Piene

Harald presented a case history that demonstrated clearly that when we commit resources to intensive forest management, we must evaluate the risks that go with it. In this case, spruce budworm on Cape Breton Island had no respect to our feeble attempt to enhance productivity through thinning. If forest protection does not go hand-in-hand with intensive forest management, we take both unnecessary and in some cases unacceptable risks.

### Henry Gross

Henry focused on pathogens and pointed out that we can use early spacing as a tool to reduce the risks of damage to future crop trees by pathogens and some insects. He did warn us, however, that thinning could have deleterious effects, particularly when the roots of thinned trees act as reservoirs for root-rot fungi that are eventually transferred to the remaining crop trees. We apparently need to be careful that we do not interfere with stands in areas of high root-rot incidence.

### Ed Telfer

Ed gave us a great deal of support for thinning from a wildlife perspective. After tracing the nature of forest succession, which includes a wildlife component, he pointed out how thinning could actually emulate the opening up of stands characteristic of both early and late successional stages. Did I say "Old Growth"? Do we have a new marketing scheme for thinning? I will not try to attribute this to Ed — he might get a bit nervous. Opening of stands and the creation of a variety of stands in the landscape all have positive impacts on wildlife species diversity. As a fringe benefit, spacing of stands may also reduce the risk to new plantations of damage from mammals — "The hares are coming!"

## SYNTHESIS OF IMPORTANT ISSUES

OK. Now what? With four diverse presentations, as I have just described, I may never forgive Fred Haavisto for shafting me with the job of trying to synthesize this session. What are the common elements? I think that most of this session comes down to the point that *we need to know why and how things are happening* and not just that they do happen. We cannot manage a system without understanding what makes it work. As I mentioned earlier, we already have a great deal of information that is sitting there waiting for us to pull it together to enhance our forest management practices. The information is in company and district office filing cabinets, in research papers, and in the several tonnes of files that seem to go with each publication. There is little question that there are also holes in our information and, hence, a need to fill these holes through either research or technology development aimed at critical gaps in the data.

A second theme that comes from both this session and the conference as a whole is the *need for better information on the responses to intervention in stand dynamics*. This is a fancy way of saying that we need better growth and yield information. It is, however, more than that. We need to ensure that those "soft green values of the forest" are not jeopardized by our actions. Although one can never reach a balance between our drive to ensure long-term wood supply and society's other needs for the forest, this latter aspect should be seen more as a challenge than as a restriction on how we manage our forests.

## RECOMMENDATIONS

I was told that I had to come up with three recommendations. This makes me nervous. An old economist friend of mine once told me that you should never make projections that have a time frame that is shorter than either your career or your life. I think that the same holds for recommendations, since you never know if you may be in the position to have to implement them some day. However, Les Reed told us yesterday that we had to take risks, so despite my better judgement, here goes.

### 1. Match forestry practices to the type of forest ecosystem and its functioning.

This recommendation tries to address our session's key point, that we need to know how and why things happen. It also points out the importance of knowing the implications of spacing and thinning for such things as wildlife, pest control, and tree/stand/forest responses. Finally, it stresses the point that we are not dealing with only one system. We have heard examples from forests across Canada, the United States and Europe. These forests do not all function in the same way. There must be local solutions developed for local problems and they must be based on a sound understanding of the forest.

### 2. Develop tools that simplify strategic thinking and planning.

As I have mentioned before, we have a great deal of information with which we can make informed decisions. We also have a series of tools such as Geographical Information Systems, the Forest Resources Inventory, the Forest Ecosystem Classification, Decision Support Systems and various databases. We have heard on several occasions, both in the growth and yield workshop and again here, that we need better models of growth relationships, particularly in managed stands. We need to put the picture together if we are to plan for the future. The development and use of computer tools for forest management is of critical importance if we are to be able to evaluate our investments in spacing and thinning against the risks of fire, insects and diseases, and variations in market and product demand.

### 3. Plan with the next generation in mind.

Gord Oldford presented the need for those of us involved in forestry to focus on sustainable development very eloquently yesterday. In addition to the need to deal with the economic, social and environmental aspects of forestry, we must ensure that future generations have access to the Canadian forest heritage. Les Reed encouraged us to dream of what could be, but I think that we need to look at both sides of the future. We need to be able to estimate how our past and present interventions in forest ecosystems will affect wood supply and other forest values in the future. In addition, climate change may be a major wild card in predicting future access to the forest resource and could, in fact, be either beneficial or detrimental. Undoubtedly, it will be both.

There you go Fred, three recommendations. Hardly specific, but I think that they can provide some guidance when we make decisions on spacing and thinning to provide space to grow.

# SUMMARY OF SESSION IV: SPACING AND THINNING OPERATIONS

*G. Swant*
*Chief Forester*
*Buchanan Forest Products*
*Thunder Bay, Ontario*

From my review of each of the talks, I have a number of questions and comments that I hope the speakers and forest managers will think about.

1. The first speaker was Mr. Tim MacKay of Dow Elanco Ltd. The major question that I have concerning this talk and about chemicals used in thinning concerns why chemical companies are continually working on new ways to "nuke" trees. Why are they not working on environmentally safe chemicals? Herbicide applications and thinning applications simply won't be used if they are not environmentally safe.
2. I was very impressed with the comments by Mr. Lennart Oloffson from Nordfor Training and Consulting. All I can say is that we have a long way to go if we are still trying to decide on whether or not to thin. Nordfor has 20 years of experience in thinning; we are lucky if we have a dozen 20-year-old plantations in northwestern Ontario. Come back and see us in 10 years.
3. Mr. Mark Ryans of FERIC talked about the technology of mechanized thinning, and it is from his talk that I propose my first recommendation. It seems to me that, in Ontario, we should be working on a machine that will harvest mature wood and also do thinning. In the forest industry, we are saying that this would be more cost effective than adapting a system from a Nordic country. My recommendation is that FERIC and the equipment companies work on a machine that can harvest mature wood and do thinnings. I have a dream that some time in the future a Swedish forester will give a lecture in Sweden to Swedish foresters on Canadian innovations in thinning. Why can we not invent this equipment?
4. I think that Mr. Tim White from Timberjack Inc. missed the point completely. We want equipment that will harvest small trees now, at a profit, so we can harvest 20-inch (51-cm) trees later on. He was worried about the size of the small trees, but we cannot avoid them; we are going to thin small trees commercially. That is a fact of life.

   Another question that I have, and one I am constantly being asked by the President of our company, is why we want a single-tree harvester. Why not a multiple-tree harvester? Such a machine would solve the problem of too many small trees.

   I thought Mr. White made a very good point that was not emphasized enough in the conference: Thinnings may replace most of the wood that is alienated by forest reserves. This is particularly important with respect to the comments by Dr. Telfer in the previous session.
5. Mr. Jeff Delaney of the Manitoba Department of Natural Resources brought me back to my Ottawa Valley days, when we conducted horse logging under ARDA (the Agricultural and Rural Development Act) and winter-works programs. I took advantage of this money to hire farmers with horses from neighboring farms and to undertake uniform white pine shelterwood cuts. These farmers had nothing to do in the winter. Under the winter-works program, the less fortunate people in the towns got out to work in the bush, doing thinnings and cleanings.

   Recommendation number two is that we try to get some of these old-style programs like ARDA and winter works back into the system. As Mr. Linus Andersson of the Swedish University of Agricultural Sciences said, precommercial and some of the commercial thinnings must be done by hand.
6. I would like to know where Mr. Max Pletch, of the Ontario Ministry of Natural Resources' Dryden office, got his labor force. I would like to see some of our cutters get involved with precommercial thinning, and I hope he will say that it was cutters from the local industry. The thing that I loved about his talk was that the biggest result he saw after the Dryden thinnings was a reduction in the rotation age. If you remember my talk, this is what made thinning economically sound for the accountants in my company.

7. I also have a question for Mr. Wayne Brown from Corner Brook Pulp and Paper, Newfoundland. Why were you so stuck on 2,000 trees per hectare? I think this was the key to your program, and it should be explained.

8. The most important point made by Mr. Al Angrignon of the New Brunswick Community College in Miramichi was the benefit of teaching good business principles to contractors through training; i.e., teaching them how to achieve productivity, to invest and to pay their debts.

This brings me back to the question I constantly encounter in my line of work: Where do the future contractors come from to cut and thin trees or to undertake all other forestry jobs? A training program answers part of that question.

My final recommendation is that each forest manager in the room go back to the office and draw up a crop plan. It may not be scientifically sound, it may have some flaws, and you may not know what the yields are, but if you do not do it, you will never get started. You will never start thinning!

# SUMMARY OF SESSION V: MANAGEMENT CONSEQUENCES

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Rather than summarize the eight papers that you have just heard on the management consequences of spacing, I would like to take this opportunity to comment on the integration of silvicultural practices — such as spacing and thinning — with tree improvement and make a couple of recommendations that, if implemented, will help with future decision making.

As forest managers, we must understand that silvicultural treatments will have an impact on the morphological and physiological condition of the trees on the site. Because of our lack of understanding of many biological interactions, we are unable to predict with certainty what effect silvicultural treatments such as spacing will have on tree form and condition. However, should we gain that understanding, we have the opportunity with tree species, particularly with boreal black spruce and jack pine, to develop cultural practices and to breed for improved traits concurrently. Agriculturists are less fortunate in that most agricultural species have been domesticated for thousands of years but only recently have they been intensively bred. The simultaneous development of both silvicultural practices and tree breeding could lead to significant gains. We can consciously breed trees to perform well under specific treatments.

The integration of silvicultural practices, particularly spacing and thinning, with tree improvement can occur at several levels, but two are mentioned here:

1. Selection during the spacing operation.

A number of papers yesterday and this morning (L. Oloffson, M. Pletch and W. Brown) mentioned the selection of crop trees during operational spacing. This might be called "tree improvement by default". The principal aim of most spacing operations is to achieve a stocking that will enhance volume growth. However, there is no reason why crews cannot be trained to identify, and leave when possible, individuals that exhibit superior height growth and straight stems, and that are free from obvious insect and disease damage. This form of selection may not amount to a measurable genetic gain, but when a hectare is reduced from 20,000 individuals to 2,000 of the better stems, you are certainly providing considerable improvement.

In Ontario, particularly in the northwest, we will likely always need huge quantities of seed for the direct-seeding program. Stands that have been spaced to favor the best trees will, when mature, be capable of providing large quantities of high-quality seed. Not only will the large, vigorous crowns of spaced stands produce more cones than those of dense stands, but the induced genetic improvement will be captured. The effort put into selecting the best individuals during the spacing operation and the gain achieved will be passed to the next generation of direct-seeded stands.

2. Tree improvement could have a significant role to play when establishing stands that are to be spaced or thinned in the future.

Tree improvement is obviously not a factor in natural regeneration and a tree-improvement program should not be designed or expected to provide seed for a direct-seeding program that requires 30,000 to 40,000 seeds/ha, except as mentioned above. A tree-improvement program could perhaps provide seed for direct seeding when using scarifers or seed-cone shelters, for which less than 10,000 seed/ha are required. Tree improvement certainly has a role to play when establishing plantations that may be thinned to favor the production of sawlog material under an intensive-management scenario.

Forest managers face the problem of making decisions on the integration of silvicultural practices with tree improvement on the basis of inadequate knowledge. We are not fully aware of the impacts on or interactions with the form and condition of trees that result from spacing. Intuitively, we believe that spacing or thinning usually have a positive effect on volume growth, particularly diameter growth; a neutral effect on stem staightness; and likely a negative effect on traits such as branch size, pruning, taper, proportion of juvenile wood and wood quality in general. We do know that there is a genetic correlation between branch diameter and stem diameter, but there may be variation within this correlation that we can exploit through tree improvement. We do not know the variability in natural pruning or the variability in the point at which juvenile wood switches to mature wood. J. Barbour has just pointed out the fact that many individual wood properties interact to determine quality, making it difficult to predict how changes in a particular property will influence the end product.

This lack of knowledge, combined with the opportunity to integrate silvicultural practices with tree improvement, leads me to my two recommendations:

1. There is a pressing need to collect data on the impacts of silvicultural practices on the morphological and physiological characteristics of trees and the magnitude of these impacts. It is not enough to know only how spacing improves growth and yield.
2. There is a need to determine the economic significance of the impacts of silvicultural treatments. Only with the economic data in hand can we make decisions on which traits deserve our attention in a tree-improvement program.

With the above information, the integration of tree improvement with cultural practices such as thinning plantations could become a reality rather than a dream.

# CLOSING REMARKS

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As symposium chairman, I have had two enjoyable tasks. The first was to delegate all the work, and the second was to have the last word. If you will bear with me for a few minutes, I would like to return to the original premise for holding this meeting.

Bill Botti's poetry inspired me to make an attempt at punishing the English language in order to make a point:

There once was a Regional Forester of renown
Who's name, quite simply, was George Brown.
We got together in the year 1983
To plan a symposium on the jack pine tree.
I suggested one topic worth considering
Was the growth response from precommercial thinning.
He said, "Sonny boy, I'm sure it would be a hit.
But establishment's the game, and about thinning,
I don't give a ****!"

George Brown and others of his era were true pioneers, and, bless their souls, they were responsible for making the incredible leaps in silvicultural practice and programs in Ontario in the 1970s and early 1980s. Needless to say, however, George's comment set me back a little.

In 1987 I had the good fortune to visit Sweden to examine plantation cleaning and thinning techniques. I was very impressed with the fact that under their conditions, mechanized commercial thinning of managed stands was a technical, operational and economic reality. Besides the tremendous market for the products of thinning, one of the main reasons for this was the recent development of the single-grip harvester. At that time in this province, this term meant a rather unfortunate one-armed tobacco farmer. I was also rather shocked to be informed that cleaning and spacing with brush saws was being conducted on a total of 350,000 ha per year.

Shortly after this trip, I again had the good fortune of visiting eight of ten provinces in Canada within a four-month period. One thing that stood out in my mind from this trip was that we have been rather busy in the past 10 years or so and have managed to put millions of trees into the ground in this country. Most of these trees have been labeled for the pulp mill, with no further stand interventions planned. Interestingly, in areas with existing sawmills, it was not uncommon to find that there were no sawlog management regimes in place. At any rate, few foresters were thinking in terms of sawlog wood quality, and many did not appreciate the fact that, in my opinion, these tightly spaced plantations won't produce much sawlog material without thinning, even if so desired. (Of course, widely spaced plantations won't produce quality wood either.)

With no current demand for the wood produced by thinning, and a feeling that the technical feasibility of thinning was a very long way off, it was not surprising that commercial thinning wasn't receiving much attention. However, in light of the apparent local wood shortages developing across the country, and as a result of my trip to Sweden, I began to question whether the day that thinning might be "technically, operationally and economically" feasible in Canada might not be that far off. If so, there was a message that had to get out.

My travels in Canada and Sweden, and the facts about the current and future plantation resources in Canada, also got me thinking about the possible opportunities out there — the type of opportunities Les Reed spoke about yesterday — "Space to Grow", with an exclamation mark!

Another opportunity I had was to work with the Precommercial Thinning Working Group of Eastern Canada. This body was essentially an information exchange group that did some very good work in developing specific suggestions on how to improve precommercial thinning operations. Out of this I had the real pleasure of getting to know Wayne Brown. Message number two was to bring experienced individuals like Wayne Brown to Ontario to give us the benefit of their knowledge in spacing.

All of this led to the suggestion that we hold this meeting. I thank Carl Winget for providing his support; it is Carl who had the inspiration for the title "Space to Grow" — very simple, but it captures the spirit of this event. I would also like to thank John Goodman and Gord Oldford for quickly jumping in with OMNR support for the meeting.

At the 1983 Jack Pine Symposium, only one paper was presented on the topic of thinning. I guess we have made some progress. "Space to Grow" has involved more than 45 speakers, rapporteurs, session chairmen and poster presenters. Speakers have come from literally halfway round the world. A tremendous effort has been expended by these people in developing a dialogue on the topic of spacing and thinning. Could you please join me in giving these people and the many dedicated organizers our heartfelt thanks.

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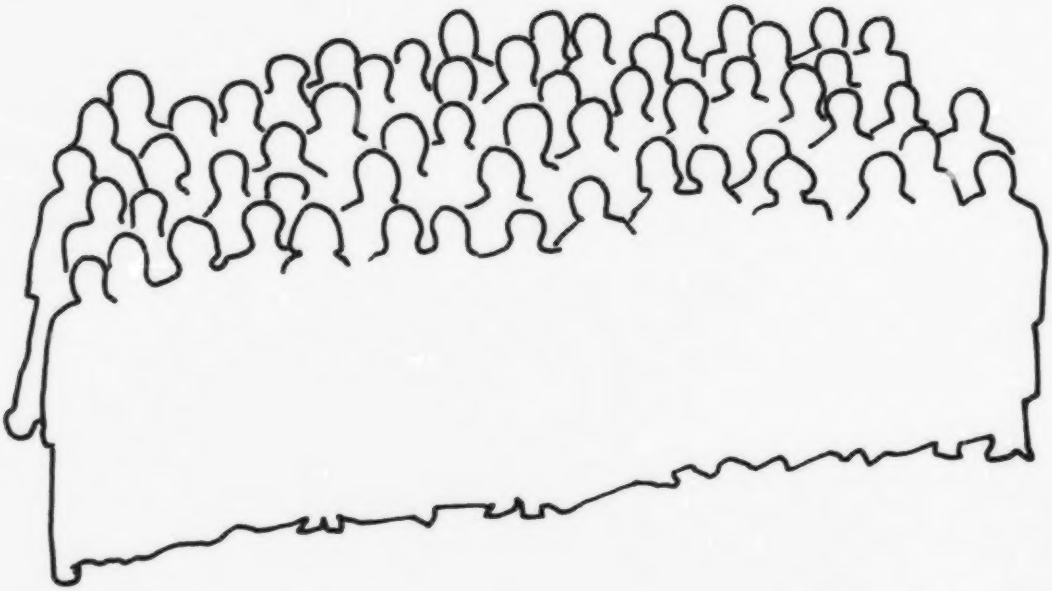

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